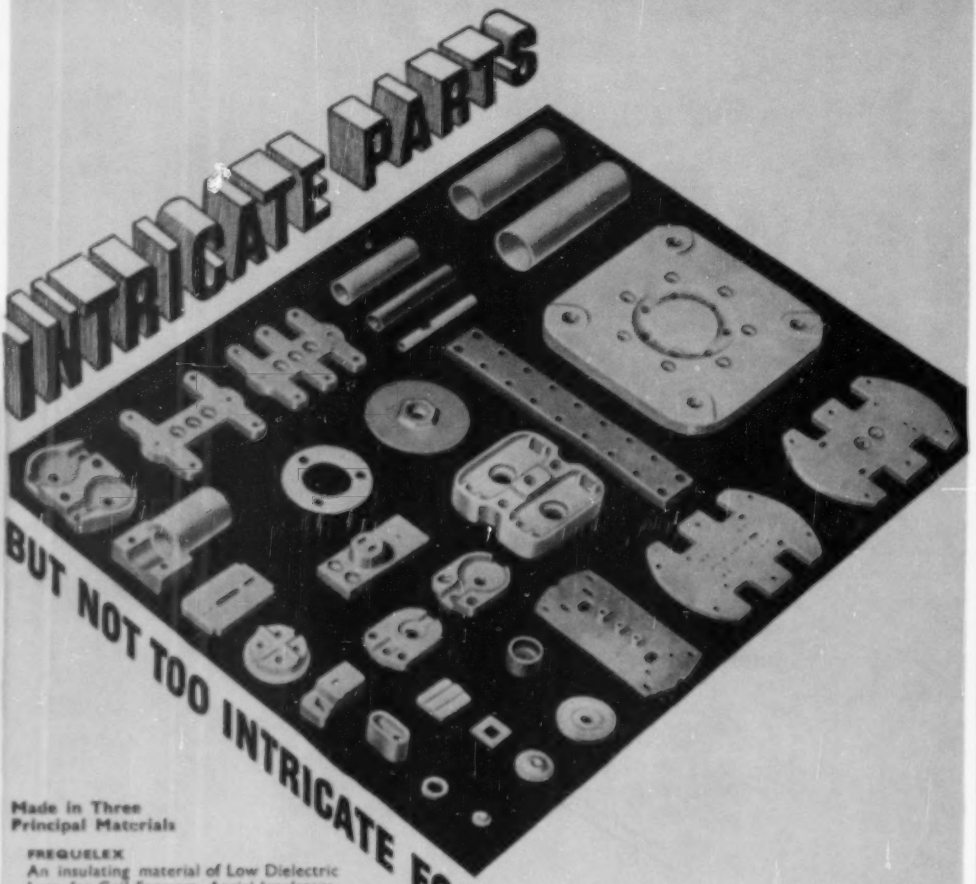
WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

MAY 1950

VOL. XXVII TWO SHILLINGS AND SIXPENCE No. 320



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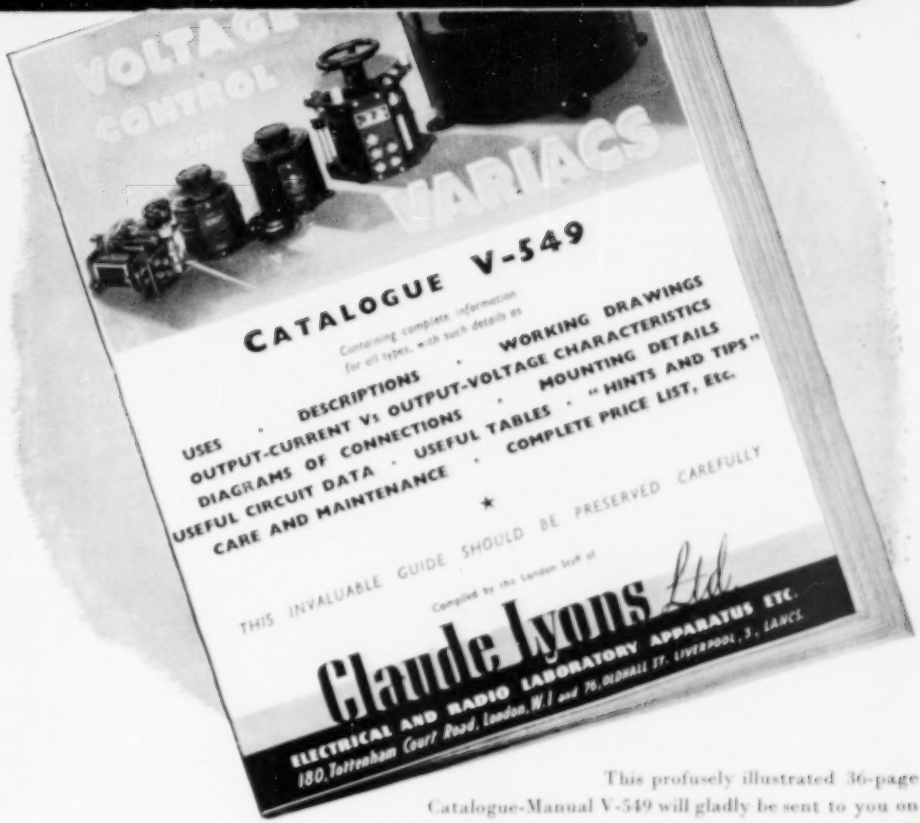
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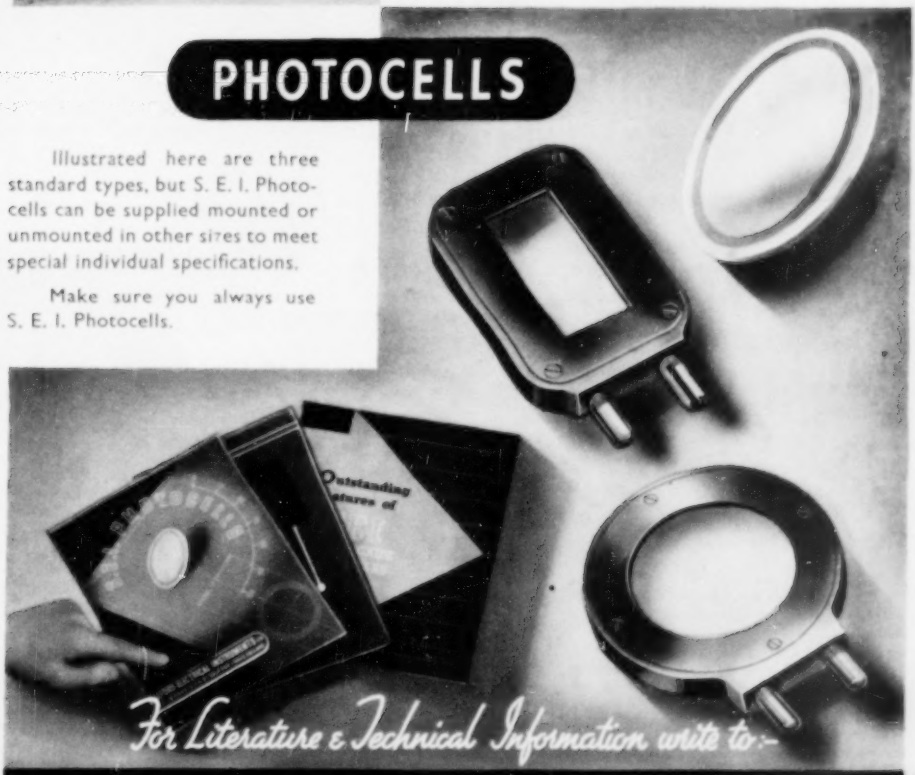

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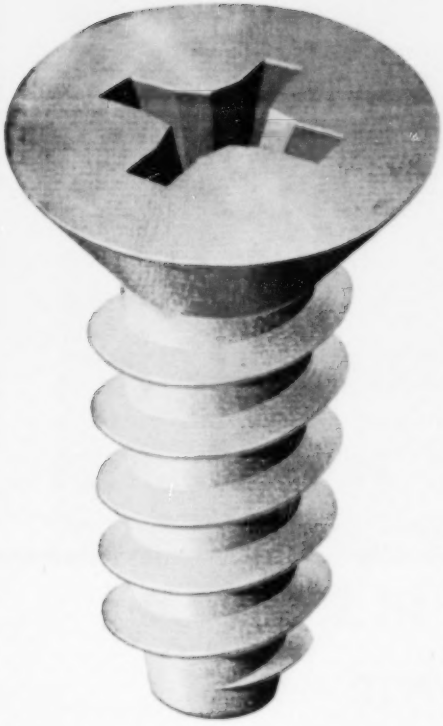

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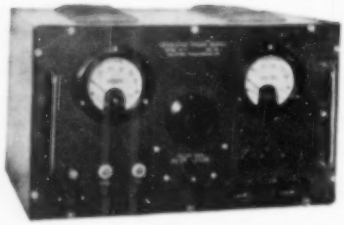

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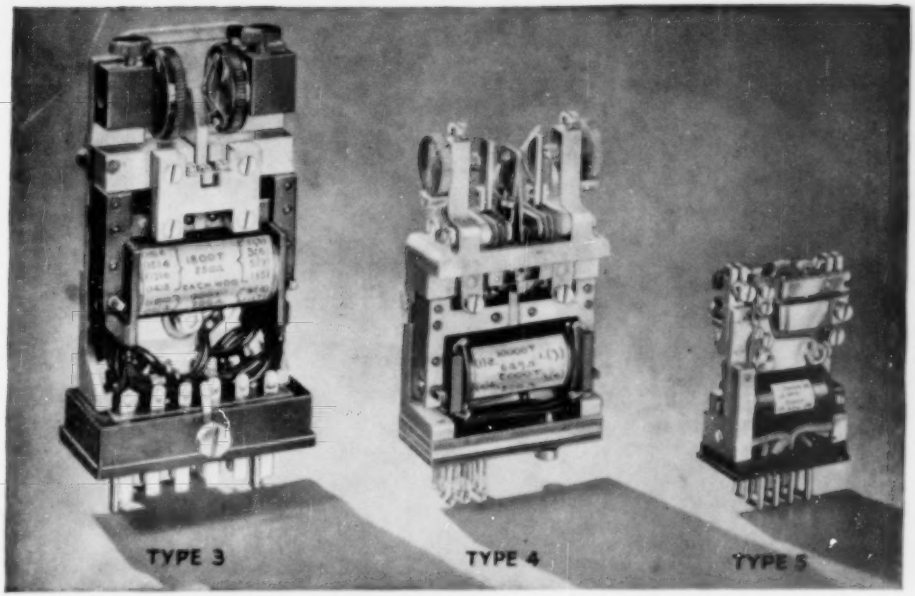

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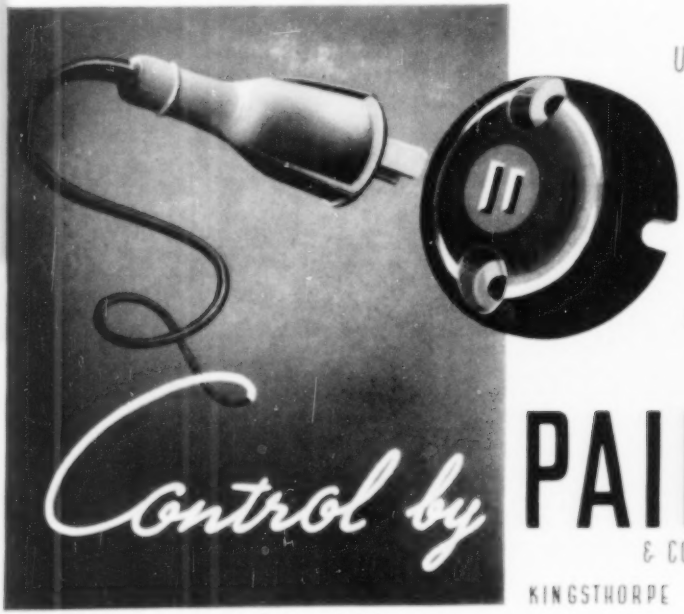

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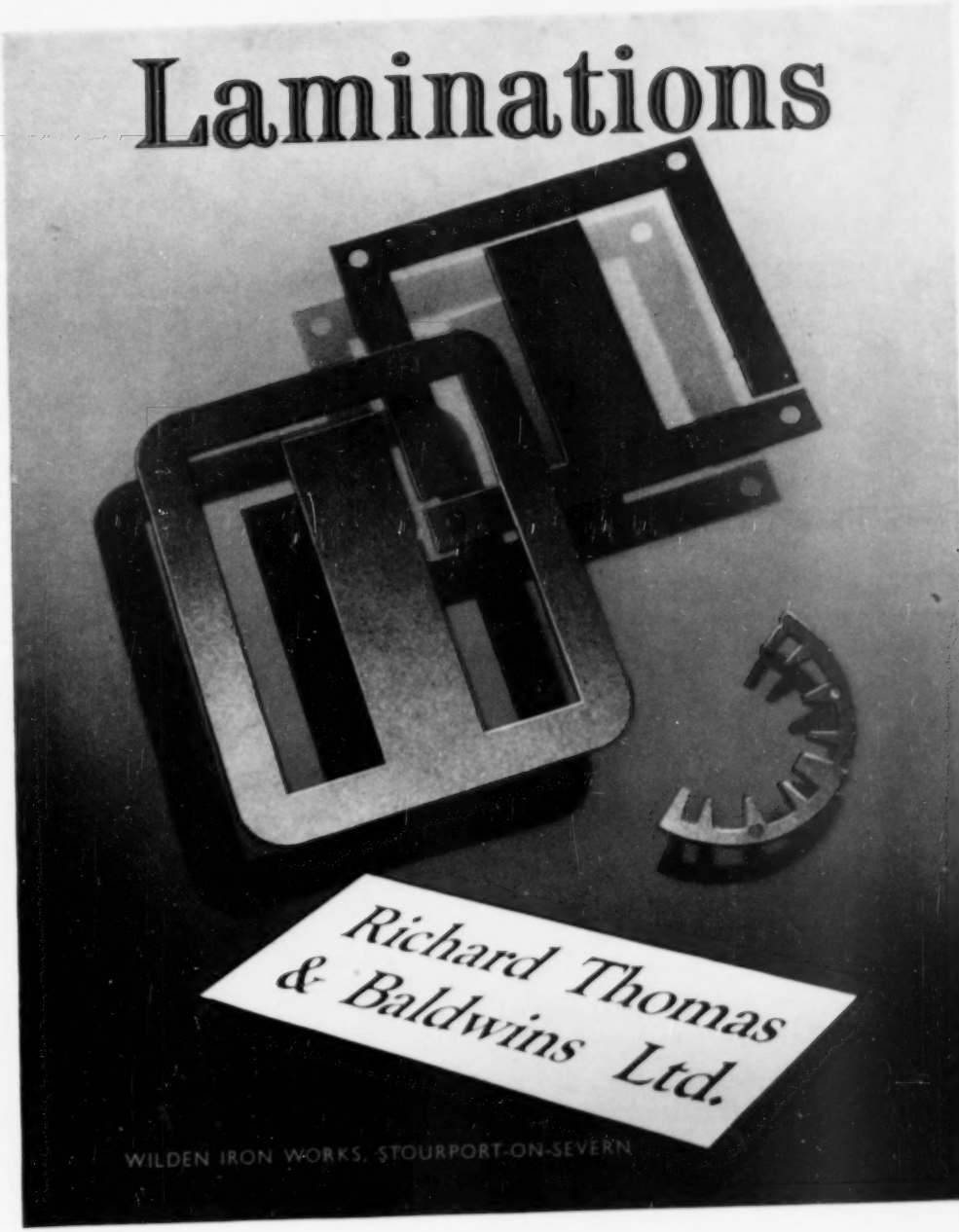
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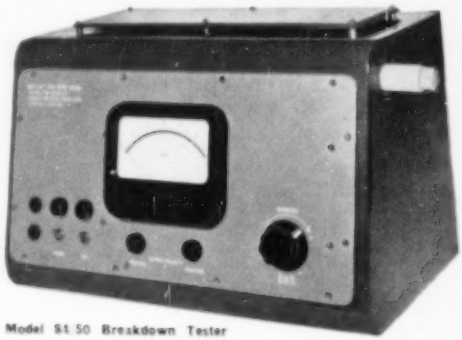

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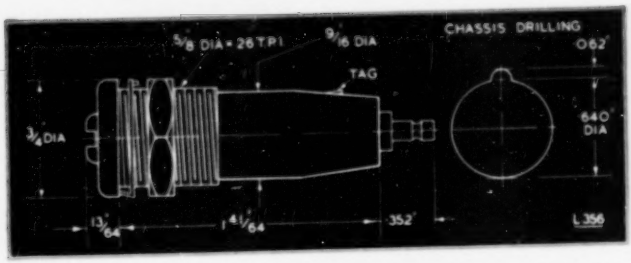

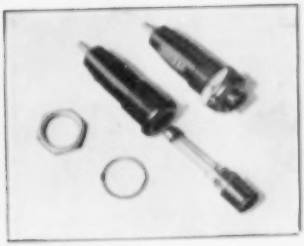

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W.4360
10H/2169
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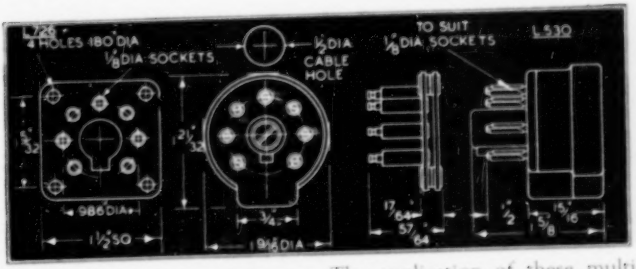

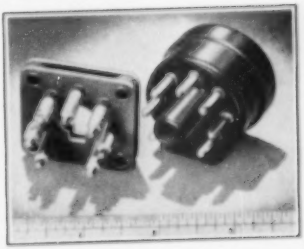

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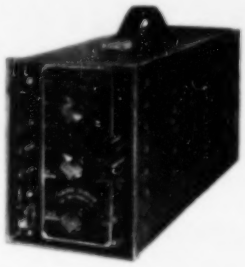

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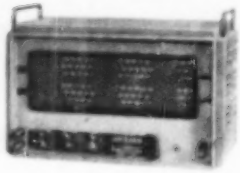

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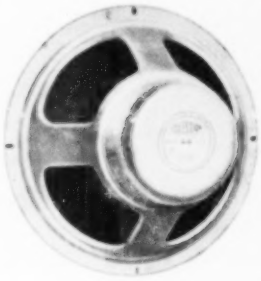

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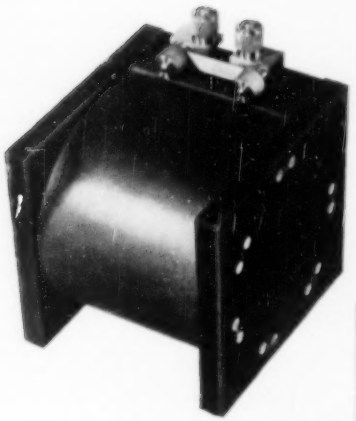

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MAY 1950

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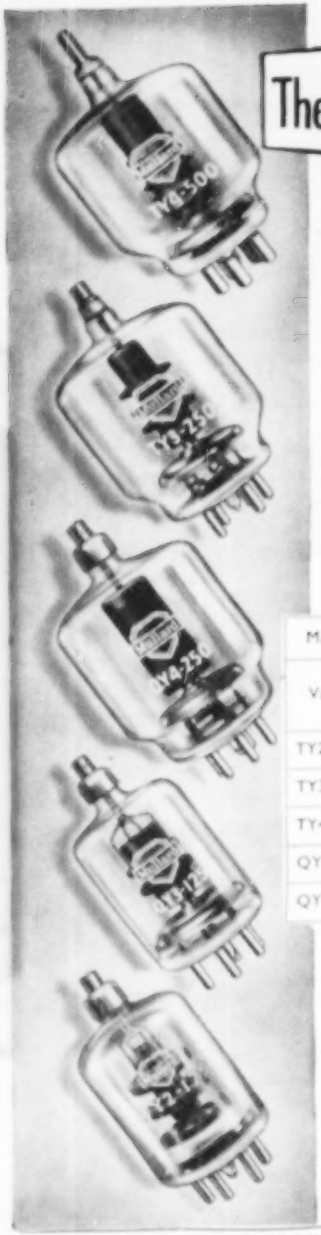

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TY2-125	osc.	2500	—	—200	200	—	40	350	360	72	200
TY3-250	osc.	3000	—	—250	363	—	70	380	830	76	150
TY4-500	osc.	4000	—	—350	550	—	100	625	1670	76	120
QY3-125	ampl.	3000	350	—150	166	35	10	280	375	75	220
QY4-250	ampl.	4000	500	—225	312	50	8	315	970	78	150

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An Electrostatic Field Problem

THE stretched elastic threads that are so often used as analogies when considering pictures of electric and magnetic fields are liable to be carried too far and to lead to false conclusions. In Fig. 1 a positively-charged sphere is situated at the centre of a large metal spherical shell. An equal and opposite charge will be induced on the inner surface of the shell and, if the charge is q e.s. units, $4\pi q$ lines of force will radiate symmetrically from the positively-charged sphere to the shell. The electric field will exert a radial force inwards on the shell and outwards on the small sphere, and anyone who has thoroughly absorbed the stretched elastic-thread analogy could be forgiven for jumping to the fairly obvious conclusion that the total force is the same on both. If the small sphere were split into two hemispheres each charged with $+q/2$ they would mutually repel each other, but the stretched elastic thread analogy would probably lead to the obvious conclusion that the apparent repulsion was really due to the attractive forces of the stretched elastic threads, and that the mechanical reaction comes on the outer shell.

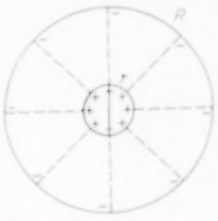


Fig. 1

How wrong all this is can be seen at once by calculating the mechanical forces at the two surfaces. At any radius x the field strength $\mathfrak{E}$ (i.e., the number of lines per cm^2) is equal to $4\pi q/(4\pi x^2) = q/x^2$. The mechanical tension is equal to $\mathfrak{E}^2/(8\pi)$; that is, to $q^2/(8\pi x^4)$ per cm^2. The total mechanical force over the spherical surface $4\pi x^2$ is, therefore, $q^2/(2x^2)$, and falls off inversely as the square of the radius, although there is no change in the number of lines of force. If the radii of the inner and outer spheres are r and R respectively, the total forces over the two surfaces are $q^2/(2r^2)$ and $q^2/(2R^2)$ and if the inner charged sphere has a radius r of 1 cm and the outer shell a radius R of 1 metre, only a ten-thousandth part of the mechanical force on the small sphere is exerted on the whole surface of the outer shell. When the small sphere is divided into two parts, it follows that only a negligible part of the mechanical reaction involved in the repulsion of the two parts comes on the outer shell, and still less on the walls of the room if the outer shell is removed. Although the stretched elastic threads radiate from the small sphere, the stress in them falls off very rapidly, as if they were being gripped by myriads of invisible hands which take the stress.

The total radial force over a half the surface of the small sphere is $q^2/(4r^2)$ and the resultant force tending to separate the two halves will be a half of this; viz., $q^2/(8r^2)$. This is what the force would be between two point charges of $q/2$ separated a distance of $\sqrt{2}r$. Similarly, the resultant force on half the large spherical shell will be $q^2/(8R^2)$ which, as we have seen, is negligibly small. Where then must we look for the missing reaction $q^2/(8r^2) - q^2/(8R^2)$? This is provided by the lateral pressure in the electric field. It is this lateral pressure that provides the myriads of invisible fingers which relieve the radial lines of the stress. The lateral pressure is also equal to $\mathfrak{E}^2/(8\pi)$ per cm^2 and if we integrate this over the plane surface separating the two large hemispheres between the

radii r and R we get for the total repulsive force

$$\int_r^R \frac{\mathfrak{E}^2}{8\pi} \cdot 2\pi x \cdot dx = \int_r^R \frac{q^2}{x^4} \cdot \frac{2\pi x}{8\pi} \cdot dx = \int_r^R \frac{q^2}{4x^3} \cdot dx$$

$$= \frac{q^2}{8}\left(\frac{1}{r^2} - \frac{1}{R^2}\right)$$

which for most practical purposes is equal to $q^2/(8r^2)$. The repulsive force in the field falls off very rapidly with increasing radius, so that about 90 per cent of the total repulsive force between the two charges is exerted by lateral pressure in the field within a radius of $3r$.

All the lines of force end normally on the spherical surface so that the ultimate force on the small hemispheres is a tension normal to the surface. At a short distance from the surface this radial tension is reduced and converted into a circumferential pressure, somewhat as shown in Fig. 2 in which the two dotted circles represent fictitious spherical shells which take up the tension of the small springs and convert it into

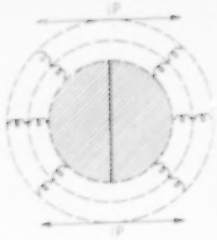


Fig. 2

compressional force at P. The repulsion of the two half spheres each charged with $+q/2$ is due primarily to the lateral pressure at P, but ultimately to the normal surface tension maintained by this lateral pressure. Although less familiar, these compressed spherical shells are just as real—or as unreal—as the stretched elastic threads.

The view that the apparent repulsion between two like charges placed close together is really due to attraction by the induced charges on the surrounding walls is thus quite wrong and due to a misconception of the nature of the forces in the electric field.

G. W. O. H.

Oliver Heaviside

THIS year is the centenary of the birth of Oliver Heaviside. He is now perhaps most widely known in connection with the E layer for, until quite recently, it was generally called the Kennelly-Heaviside layer. Kennelly in the U.S.A. and Heaviside in this country suggested at about the same time that such a layer might exist and that its presence would account for long-distance wireless propagation. In his article "Theory of Electric Telegraphy," which was written in June 1902 and published in the tenth edition of "Encyclopædia Britannica," Heaviside wrote "There may possibly be a sufficiently conducting layer in the upper air. If so, the waves will, so to speak, catch on to it more or less. Then the guidance will be by the sea on the one hand and the upper air on the other."

Probably his most important work, however, was in the development of operational methods of solving differential equations. Although his methods were not acceptable to many mathematicians of his day, they have stood the test of time and are now commonly used.

The Heaviside unit-impulse, or step-function, is famous and the analysis of the transient response of circuits is probably more often carried out by his basic methods than by any other. He originally developed them mainly for investigating the properties of cables which then formed the chief method of telegraph transmission. His theoretical analysis showed that for the distortionless transmission of a signal it was necessary properly to relate the capacitance, inductance, resistance and leakance of a cable, and that the natural inductance of a cable was much too small. He suggested, therefore, that the dielectric of the cable should be loaded with finely divided iron and later, he produced the alternative, and more practical, suggestion that the required increase of inductance should be obtained in lumps by means of inductance coils inserted in series with the cable at intervals.

This idea of loading a cable was too revolutionary for the times, 1893, and it was not for seven years that it was given a trial by Prof. M. I. Pupin at Columbia University. The results so confirmed Heaviside's theory that loading soon became normal practice and is still in common use.

Oliver Heaviside was born on 13th May 1850 at 55 King St., Camden Town and he died in Torquay on 4th February 1925. Wireless and electrical communication owe very much to him, how much is only now becoming widely realized. He was too much in advance of his generation for his work to be properly appreciated at the time. This appreciation, however, was not entirely withheld during his lifetime for, in his later years, he received some part of the honour due to him.

W. T. C.

SECONDARY-EMISSION VALVE

Wideband Amplifier for Decimeter Waves

By G. Diemer and J. L. H. Jonker

(Philips Research Laboratories Eindhoven, Netherlands)

SUMMARY.—An experimental secondary-emission valve is described. The high figure of merit ($g_m/C = 3.0$ mA/V-pF) that is obtained by adding one stage of secondary emission to an earthed-grid triode of rather conventional construction makes the valve useful as a wideband amplifier for those cases where a very low noise figure is not required; typical figures are: at 1 m wavelength 30 db gain (G) with a bandwidth (B) of 3.5 Mc/s, at 50 cm $G = 15$ db with $B = 20$ Mc/s, at 30 cm $G = 10$ db with $B = 10$ Mc/s. The maximum power output is for $\lambda > 1$ m about 1.5 watts. At 7 m wavelength the noise figure amounts to 12 db; this rather high value is due to secondary emission. It is shown that for this secondary-emission noise a kind of space-charge smoothing effect exists.

IT is well known that the high-frequency performance of wideband amplifiers is mainly governed by the ratio of the mutual conductance g_m to the valve capacitance C (provided that the ohmic losses are made as small as possible). In those cases where one is limited by the available cathode emission rather than by the static anode dissipation, it is possible to increase both the mutual conductance and the anode current by a factor δ by adding one stage of secondary emission (in practical cases δ may amount to about 5)[1]. With careful design the capacitance need not be increased by this. In those cases where the static anode dissipation of the normal valve is already a maximum, it is better to keep the anode current unchanged when adding the secondary-emission stage, thus decreasing the cathode current I_k by a factor δ, which results in a considerable decrease of input damping and an increase of g_m/I_k. In this article it will be shown that high values of g_m/C and g_m/I_k can be obtained in such a secondary-emission valve, even when the cathode-grid construction is rather conventional (no small distances; mounted on mica).

Wagner and Ferris[2] have already described a secondary-emission valve operating at $\lambda = 60$ cm. Though the valve described here is of a simpler electrode construction, which is possible because of the good life obtained with a caesium-oxide emitter[3], it operates up to frequencies of 1000 Mc/s ($\lambda = 30$ cm). A drawback of the secondary-emission valve is its relatively high noise figure. As is well known the random fluctuations of δ introduce an additional noise.[4] Noise measurements on the new u.h.f. secondary-emission valve have been published by Van der Ziel and Versnel[5]; the minimum noise figure is 12 db.

1. Construction and Static Data

Figs. 1 and 2 give cross-sections of the valve, and the following points are of particular interest.

(a) The valve is of cheap and simple construction; it is an earthed-grid triode in which the electrodes are mounted on mica. The grid wires have a diameter of 35 μ; the distance d_{kg} between the cathode surface and the centre of the grid wires is 120 μ.

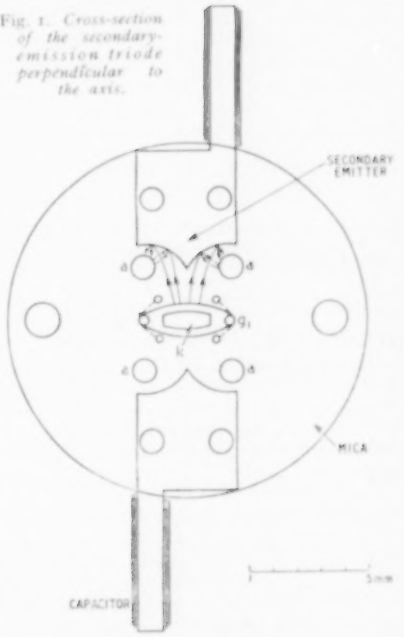


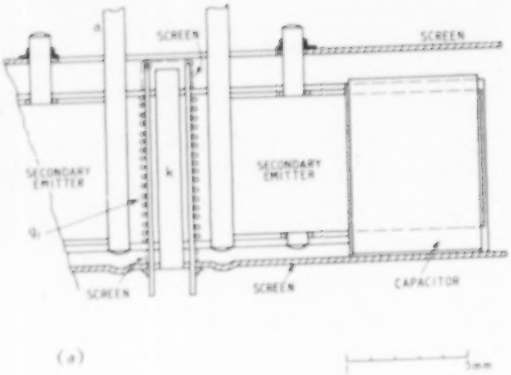
Fig. 1. *Cross-section of the secondary-emission triode perpendicular to the axis.*

(b) Ohmic losses are reduced by connecting several molybdenum pins in parallel and using broad copper-plated connectors within the valve.

(c) A small value of the valve capacitances is obtained by using a special electrode con-

MS accepted by the Editor, September 1949

struction, developed with the help of large scale models on a rubber sheet[8]; the primary beams are focused by small focusing rods on a V-shaped secondary emitter. The anode (from which the output signal has to be taken) consists of four 1-mm molybdenum rods, directly sealed through the powdered-glass bottom; in this way both the r.f. and heat conductivity are good.



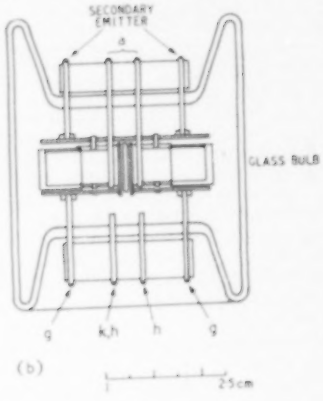


Fig. 2 (above). *(a) Electrode construction on a larger scale.*
(b) Cross-section of the valve through the axis of the cathode.

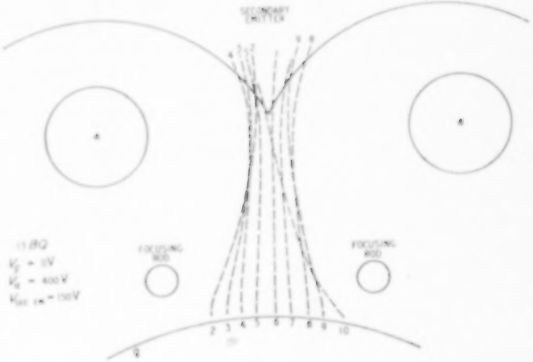


Fig. 3 (right). *Electron trajectories drawn from a photograph from a large-scale model of the valve on a rubber sheet:* $V_{g1} = 0$ V; $V_{sec.em.} = 150$ V; $V_a = 400$ V.

(d) The spread in transit time should be as small as possible. For this reason, as well as for the reason (a) mentioned above, only one stage of secondary emission is used. Fig. 3 gives a drawing according to a photograph taken from rubber-sheet experiments. From such photographs an estimate of the spread in transit-time can be made (see below).

(e) Feedback from the anode to the cathode is made very small by the earthed-grid construction with good internal shielding, while the secondary emitter is connected to the internal grid shield by a built-in capacitor, the cooling fin being one of the capacitor electrodes. The valve is 'double-ended,' the leads of the secondary emitter and of the grid consist of a ring of pins connected in parallel and adapted for coaxial input and output circuits.

(f) A high value of the coefficient of secondary emission as well as of the life is obtained for caesium oxide on copper, by making the temperature of the secondary emitter as low as possible. This low temperature results from the 'open' electrode construction: the secondary emitter is heated very little by radiation from the anode and cathode. The secondary emitter is provided with cooling fins.

(g) The electron optics for the primary and the secondary electrons should be such that for a large range of voltages at the secondary emitter and at the anode both the trajectories of the primaries and of the secondaries are 'good'; that is to say, (1) for a high value of V_a no primaries should be lost by going directly to the anode and (2) for low values of $V_a - V_{sec.em.}$ the field strength at the secondary emitter should remain everywhere such that all secondaries are drawn away.

These two conditions are more or less contradictory when using an electrode arrangement

like that of Fig. 1. The effective value of $\delta = I_a/I_k$, (where I_k is the cathode current and I_a the anode current) was measured as a function of $V_a - V_{sec.em.}$ for a series of valves having different elec.rode spacings; the voltage of the secondary emitter was constant ($V_{sec.em.} = 150$ V).

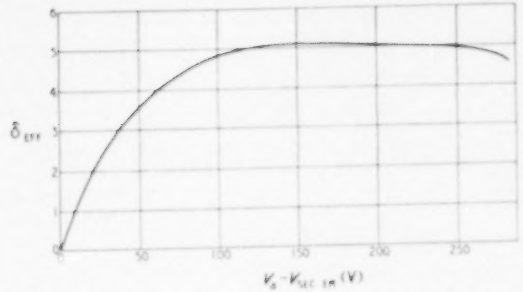
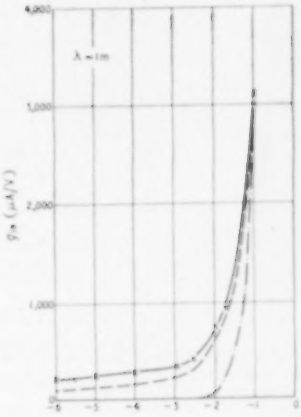


Fig. 4 (above). *Effective value $\delta_{eff} = I_a/I_k$ of the coefficient of secondary emission versus voltage difference between anode and secondary emitter. $V_{sec.em.} = 150$ V; $I_a = 10$ mA. I_k = total cathode current.*

Fig. 5 (right). *Input conductance $g_{i\,eff}$ of the secondary-emission triode at $\lambda = 1$ m as a function of control grid voltage V_{g1}. $V_a = 300$ V; $V_{sec.em.} = 150$ V. ——— Total conductance at $\lambda = 1$ m; – – – – – – electronic conductance; – · – · – · – static value of the input slope $g_{ms} = dI_k/dV_g$.*



In Fig. 4 a curve is given for the valve that proved to be the best compromise: for a large range of V_a-values δ has nearly the maximum value.

In Table I different static values of the valve characteristics are given.

Attention may be drawn to the high value of the amplification factor μ (400) which in earthed-grid amplifiers is important for a high energy gain (see K. S. Knol and A. van der Ziel)[7]. From the electrode arrangement shown in Fig. 1 it may be seen that, indeed, the anode rods have a very small 'Durchgriff' through the control grid.

TABLE I

Control-grid voltage (volts)	1.1
Anode current (mA)	18
Anode voltage (volts)	330
Sec. em. voltage (volts)	150
Coeff. of sec. em. $\delta_{eff} = I_a/I_k$	4.5
Mutual conductance $g_m = \frac{d I_a}{d V_g}$ (mA/V) ..	24
Maximum anode dissipation (watts)	6
Amplification factor μ	400
Valve capacitance C_{gk} (pF)	4.6
C_{aa} (pF)	3.3
C_{ak} (pF)	0.018
Band merit $\frac{g_m}{C_{aa} + C_{ak}} \left(\frac{\text{mA}}{\text{V - pF}}\right)$	3.0

2. U.h.f. Properties of the Valve

2.1 *Input and output conductance*

The input and output conductance of the valve were measured at 1 m wavelength ($f = 300$ Mc/s) by means of a coaxial Lecher wire. The method of measurement was the same as

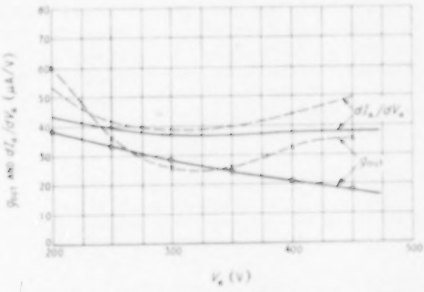


Fig. 6. *Electronic output conductance g_{aa} of the secondary-emission triode as a function of anode voltage V_a (full drawn line) and static value of the output conductance $g_a = dI_a/dV_a$ (dotted line).*

described by Van Hofweegen[8]. Figs. 5 and 6 give these conductances as a function of control-grid voltage and anode voltage respectively. From these figures the u.h.f. values of the electronic conductances may be compared with the corresponding static value. For normal operating voltages ($V_a \approx 300$ V) the u.h.f. electronic output conductance is smaller than the corresponding static value, as might be expected from the phase angle of the mutual conductance due to transit-time effects (see also Section 2.2). The relatively large input damping at large negative values of V_{g1} which varies nearly as $|V_{g1}|^{-2}$

must be explained as total-emission damping caused by electrons that return in front of the potential minimum (see also G. Diemer and K. S. Knol[8,10]).

Together with the measurements of the conductance the corresponding valve lead inductance could be determined. In Table 2 a survey of the results is given, including the resonance wavelength of the short-circuited input and output leads.

TABLE 2

Lead inductances and total valve conductances at $\lambda = 1$ m.

	cold valve	warm valve $V_{g1} = -6$ V, $I_a = 0$ mA	warm valve $V_{g1} = -1.4$ V, $I_a = 12$ mA
Input conductance (μA/V)	60	200	~3000
Output conductance (μA/V)	20	20	55

	input	output
Lead inductance (10^{-8}H)	0.9	0.8
λ_{res} (cm)	40	30

As may be seen from the conductances of the cold valve, the ohmic losses are small; this is important for a high energy gain (see Van der Ziel[11]).

The small values of the lead inductances together with the small valve capacitances result in a high resonant frequency of the short-circuited valve.

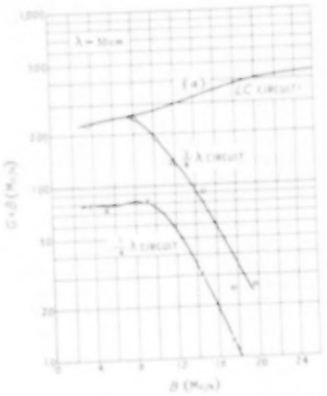


Fig. 7. *Bandmerit $G \times B$ versus bandwidth B for two different lengths of the Lecher-wire circuits at $\lambda = 30$ cm; $V_{g1\,opt.} = 130$ V; $V_a = 420$ V; $V_{g1} = -0.5$ V. Curve (x): theoretical curve for an LC-circuit.*

2.2 Bandwidth and gain at wavelengths below 1 m.

These measurements were performed by means of the matching transformers of Van Hofweegen and Knol[12] in the well-known way. The bandwidth is here defined as being the width between the 3-db points. Care was taken that the coaxial connections between the valve and the transformers were made as small as possible in

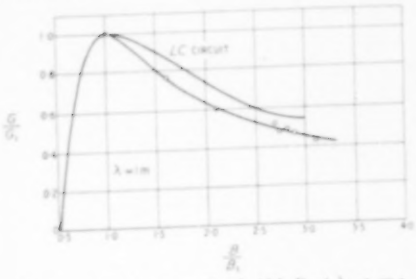


Fig. 8. *Gain G versus bandwidth B at $\lambda = 1$ m; G and B are varied by mismatching. G_1 = optimum gain, B_1 = bandwidth at optimum gain.*

order to avoid a decrease of bandwidth. Nevertheless, in most of the measurements the bandwidth B was smaller than could have been obtained by an LC-circuit, as may also be seen from Fig. 7 where the bandmerit $G \times B$ is plotted versus B, both for the Lecher wires (experimental) and for an LC-circuit (theoretical) for the case where feedback can be neglected. In our case the feedback due to the internal resistance of the valve is, indeed, very small because of the high value of the amplification factor. The bandwidth was varied by mismatching the output. At $\lambda = 1$ m, where we could work with a $\lambda/4$ Lecher wire, the discrepancies were much smaller (see Fig. 8). Probably part of the discrepancies must be ascribed to the influence of feedback capacitance between anode and cathode.

Fig. 9 shows G and B as a function of anode voltage. The full-drawn line refers to a different type of experimental valve, which had a greater distance between the anode and the secondary emitter. In Fig. 10 G and B are shown as a function of frequency for the same valves as in Fig. 9. The gain decreases greatly with increasing frequency, especially for the valve with the larger electrode distances. With a higher anode voltage the decrease is smaller. From this we conclude that, especially at the upper frequency limit, transit-time effects have a large influence. We tried to predict this decrease of gain by computing the input and output damping and the mutual conductance according to the well-known methods of transit-time theory (see,

e.g., Bakker and De Vries[13]) including the influence of spread in transit time of the primaries and the secondaries (see Malter [14]) and of ohmic losses in the electrode leads, the latter by extrapolating from the values measured at 300 Mc/s according to a 5/2-power law. In doing so, it was shown, that at 1 m wavelength both the bandwidth and the gain agreed rather well with the calculated values, but the decrease of gain at higher frequencies was much faster and the increase of bandwidth smaller than might be expected from the two effects mentioned above. Possible causes for this are :—

(*a*) the influence of feedback by the capacitance between the anode and the cathode, which in the neighbourhood of 1 000 Mc/s can no longer be neglected (see also Van der Ziel and Knol[2]; the formulae given by the latter authors are, however, difficult to apply in our case because our electrode arrangement is rather complicated) ;

(*b*) the influence of space charge, which in the rubber-sheet experiments could not be taken into account, but which may result in a larger spread in transit time than is predicted by models of the electron trajectories as shown on the rubber sheet.

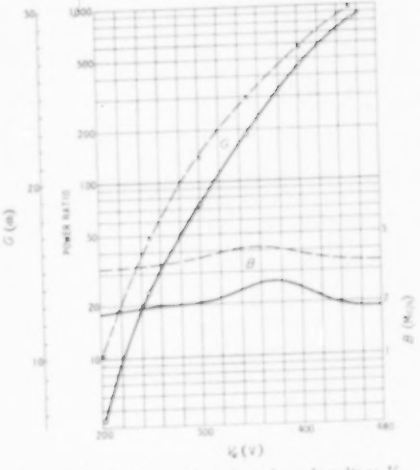


Fig. 9. *G and η as a function of anode voltage V_a with $\lambda = 1$ m. $V_{accum.} = 150$ V ; $V_{s1} = -0.5$ V. The dotted curves are for a normal valve similar to that of Fig. 1 and the full-line curves for a valve with greater spacing between the output electrodes.*

2.3 *Power output v. frequency.*

The secondary-emission valve has a lower efficiency than a pentode or a beam tetrode, because

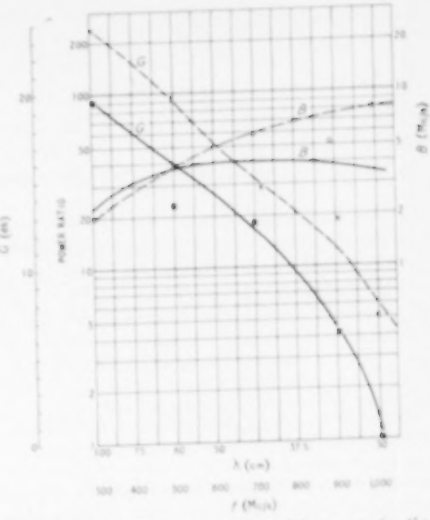


Fig. 10. *G and η as a function of frequency for the valves referred to in Fig. 9. $V_{s1} = -0.7$ V.*

a certain amount of energy is lost as constant heat dissipation of the secondary emitter and the $I_a - V_a$ characteristic has not such a sharp knee as have other valves (this may be seen from the δ-curve given in Fig. 4).

From the static characteristics for long wavelengths a maximum efficiency of about 30% may be estimated.

In Fig. 11 the efficiency η is plotted against λ. We see that, for $\lambda > 1$ m, $\eta \approx 30\%$. Near the short-wave limit ($\lambda \approx 30$ cm) the efficiency decreases rapidly due to the same causes that decrease the gain. In the same illustration curves are given for the driving power P_i and the output power P_o.

2.4 *Noise measurements.*

For the calculations and some of the measurements on the noise of this valve we refer to Van der Ziel and Versnel[8], the following formula for the noise figure F can be derived from their article :

$$F - 1 = x = \frac{\epsilon R_e + \dfrac{K-\delta}{\delta}\cdot\dfrac{e}{2kT} I_k (R_e + R_a)^2}{R_a} \qquad \ldots\ldots\ldots\ldots \quad (1)$$

in which R_e = electronic input resistance

$\epsilon = \dfrac{R_n}{R_e}$, R_n being the noise resistance due to shot noise

e = electronic charge

k = Boltzmann's constant

T = room temperature (°K)

δ = coefficient of secondary emission =

$$\frac{I_a}{I_k} = \sum_m \beta_m m \; ; \; K = \frac{1}{\delta} \sum_m \beta_m m^2.$$

β_m being the probability of the emission of m secondaries due to one single primary electron.

Formula (1) is valid under the following assumptions:

(a) the conductances are purely electronic

(b) partition noise of the primaries is negligible

(c) no space charge between the anode and the secondary emitter.

The measurements reported by Van der Ziel and Versnel at $\lambda = 7$ m agreed rather well with Equ. (1), giving a minimum noise figure $F = 16$ (≈ 12 db) at a suitably chosen value of the aerial resistance $R' = 500\ \Omega$. (See Fig. 12.)

In order to investigate whether the influence of the space charge between secondary emitter and anode might result in a noise suppression of the secondary-emission noise, similar to the well-known cushion effect of the space-charge-limited primary emission, some additional noise measurements were performed for a large range of anode and secondary-emission voltages*. At small values of $V_a - V_{secm}$ we found the experimental values to be smaller than the theoretical. In this case there is a large space charge near the secondary emitter. Because, especially, the high momentary values of δ contribute to K (and so to the noise) and because these large amounts of secondaries per single primary electron will be correlated to small initial velocities of the secondaries, one must expect that these large momentary values of δ will be more or less suppressed by space charge in front of the secondary emitter. We think this effect to be the cause of the phenomenon mentioned above. The effect is, however, not large enough to reduce the secondary-emission noise to a value that would be of the same order of magnitude as the primary shot-effect noise.

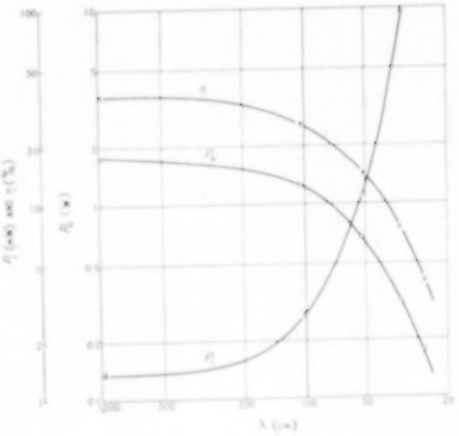


Fig. 11. *Output power P_u, input power P_i and efficiency η as a function of frequency.*

According to Van der Ziel[5] lower noise figures may be obtained by working with a still higher value of g_m/I_k; this could be done with smaller distances between cathode and control grid, but it introduces a more complicated valve construction.

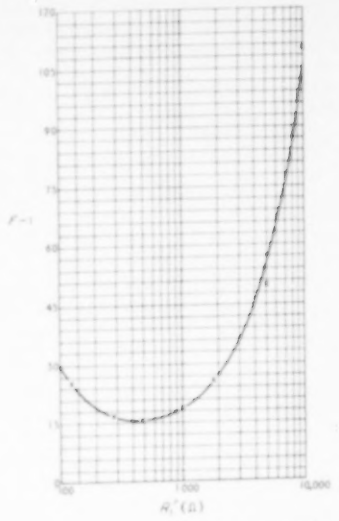


Fig. 12. *Noise of the secondary-emission valve at $\lambda = 7$ m. $\alpha = F - 1$ as a function of aerial resistance R_1 according to Van der Ziel and Versnel*[8].

3. Conclusions

It is possible to arrive at very high figures of merit for a triode of rather simple construction, by introducing one stage of secondary emission. This makes wideband amplification up to bandwidths of more than 20 Mc/s possible at decimeter waves. Because of its relatively high noise figure the valve is especially useful for those purposes where minimum noise figures are not required (last stages of i.f. amplifiers, power amplifiers).

* These measurements were performed with the collaboration of Dr. K. S. Knol and Mr. A. Versnel.

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PHASE DISTORTION IN FEEDERS

Effect of Mismatching on Long Lines

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1. Introduction

It is well known that variations of delay time with frequency for any unit of a radio system can cause a distortion of the signal. A mismatch at the end of a long feeder is one such source of variable delay, and an investigation of its effects has been initiated by Friis.[1] He finds the phase delay for a constant frequency input as a function of that frequency, but the results are not immediately applicable to frequency-modulated signals, and it is necessary to apply the variable-frequency analysis of Carson and Fry and others[2]. When this is done, a serious limitation of the method becomes apparent: with feeder lines of any appreciable length, the phase changes so rapidly with frequency that the first few terms of the expansion are insufficient, with the result that for a complete result the work becomes very clumsy and laborious. A fresh approach therefore seems desirable. This is provided by considering the system to support a series of running waves of various instantaneous frequencies, and reflected within the confines of the feeder, rather than the constant-frequency standing-wave formulation used by Friis.

2. Production of Waves in the Feeder

Let us consider an injected signal of carrier frequency f_c frequency modulated by a single tone video signal $\Delta f \cdot \sin(2\pi f_a t)$ where Δf and f_a are respectively the peak frequency deviation and the modulating frequency. We write $\omega_c = 2\pi f_c$, $\Delta\omega = 2\pi\Delta f$ and $\omega_a = 2\pi f_a$, so that the modulated carrier can be written as

$$\cos\left[\int(\omega_c + \Delta\omega \sin \omega_a t)dt\right] = \cos\left[\omega_c t + s(t)\right]$$

where $s(t) = -(\Delta\omega/\omega_a)\cos\omega_a t$

If the signal is sent along a line of length l, a portion of the wave, depending on the mismatch at the far end, is reflected, and returns towards the transmitter. If the latter is also mis-matched, a portion of the reflected wave is sent out along the line again, and supplements the wave actually being transmitted at the time, and which is of a slightly different frequency, since the wave is frequency modulated. The wave leaving the feeder at any instant is accordingly a composite one, being composed of waves generated at different times, but delayed by reflections within the feeder. There will, of course, be multiple reflections, but if the mismatches are small, the dominant interference comes from that wave which has been reflected but once from each end of the feeder before leaving it.

If we introduce the time delay τ along the feeder, and the group velocity, v, of the waves, then $\tau = l/v$ and we find for the transmitted signal, $S(t)$

$$S(t) = \cos\left[\omega_c t + s(t)\right] + r_1 r_2 e^{-2\alpha l}\cos\left[\omega_c(t - 2\tau) + s(t - 2\tau) + \theta_1 + \theta_2\right] \quad \ldots \quad (1)$$

Here, r_1, r_2 and θ_1, θ_2 are respectively the reflection coefficients and phase changes occurring at each end of the feeder, whilst α is the attenuation constant for the line. Unless τ is such that $s(t - 2\tau) = s(t)$ (a case treated later), the two terms of equation (1) will be of different frequencies, so that the composite signal will involve $s(t)$ in a non-linear way, with consequent distortion.

3. Production of Phase Distortion

At reception, we assume that the wave is first amplitude limited, and then put through the discriminator networks, which produce an output proportional to the instantaneous frequency of the signal $S(t)$. Now equation (1) can be put in the form

$$S(t) = A\cos[\omega_c t + s(t)] + B\sin[\omega_c t + s(t)]$$

where

$$A = 1 + r_1 r_2 e^{-2\alpha i}\cos[2\omega_c\tau + s(t) - s(t-2\tau) - \theta_1 - \theta_2] \quad .. \quad .. \quad (2)$$

and

$$B = r_1 r_2 e^{-2\alpha i}\sin[2\omega_c\tau + s(t) - s(t-2\tau) - \theta_1 - \theta_2]$$

This follows by putting $\omega_c(t-2\tau) + s(t-2\tau) + \theta_1 + \theta_2 = [\omega_c t + s(t)] - [2\omega_c\tau + s(t) - s(t-2\tau) - \theta_1 - \theta_2]$ in the second term of equation (1) and expanding.

Equation (2) can be re-written $S(t) = \sqrt{A^2 + B^2}\cos[\omega_c t + s(t) - \phi]$ where $\tan\phi = B/A$. The amplitude limiting removes the factor $\sqrt{A^2 + B^2}$ so that ϕ represents the phase distortion due to the mis-matches. Since $B \leqslant r_1 r_2 e^{-2\alpha i}$, which is assumed small, and $A \approx 1$, ϕ will be small. This gives the approximation $\phi \approx B$.

Now the output of the discriminator networks is proportional to the instantaneous frequency of the amplitude-limited signal, and hence to $\omega_c + s'(t) = d\phi/dt$. Of this, ω_c can be ignored while $s'(t) = \Delta\omega\sin(\omega_a t)$ represents the recovered signal. The last term contains the distortion. Carrying out the differentiation we get an output

$$\Delta\omega\,.\,\sin(\omega_a t) - d/dt\,\{r_1 r_2 e^{-2\alpha i}\sin[2\omega_c\tau + s(t) - s(t-2\tau) - \theta_1 - \theta_2]\} \quad (3)$$

Now $s(t) - s(t-2\tau) = 2\Delta\omega\tau\,.\,\sin\{\omega_a(t-\tau)\}\sin(\omega_a t)/\omega_a\tau$.

The quantity $2\Delta\omega\tau\,.\,\sin(\omega_a\tau)/\omega_a\tau$ which occurs frequently will be denoted by y. Expanding formula (3) we get for the output

$$\Delta\omega\sin(\omega_c t) - r_1 r_2 e^{-2\alpha i}\sin(2\tau\omega_c - \theta_1 - \theta_2)d/dt\left[\cos\{y\sin\{\omega_a(t-\tau)\}\}\right] + r_1 r_2 e^{-2\alpha i}\cos(2\tau\omega_c - \theta_1 - \theta_2)d/dt\left[\sin\{y\sin\{\omega_a(t-\tau)\}\}\right] \quad .. \quad .. \quad .. \quad (4)$$

4. Harmonic Production

If we use in (4) the Fourier-Bessel expansion of $\sin\{y\sin\{\omega_a(t-\tau)\}\}$ and $\cos\{y\sin\{\omega_a(t-\tau)\}\}$, we can find the various harmonics produced. Ignoring the small amount of recovered signal that appears from the distortion terms, we find

Recovered Signal

$$\Delta\omega[\sin(\omega_a t)]$$

Second Harmonic

$$2r_1 r_2 e^{-2\alpha i}(2\omega_a)\mathrm{J}_2(y)\sin(\theta)\,[\sin\{2\omega_a(t-\tau)\}]$$

Third Harmonic

$$2r_1 r_2 e^{-2\alpha i}(3\omega_a)\mathrm{J}_3(y)\sin\left(\theta + \frac{\pi}{2}\right)[\cos\{3\omega_a(t-\tau)\}]$$

Fourth Harmonic

$$2r_1 r_2 e^{-2\alpha i}(4\omega_a)\mathrm{J}_4(y)\sin(\theta + \pi)\,[\sin\{4\omega_a(t-\tau)\}]$$

etc. .. (5)

where $\theta = 2\tau\omega_c - \theta_1 - \theta_2$

In this equation, the last factor in square brackets is the form of the harmonic, and the rest of the expression is its amplitude. $\mathrm{J}_2(y)$, $\mathrm{J}_3(y)$, etc., are Bessel functions, and are tabulated in, for example "Tables of Functions," p. 156 *et seq.* by Jahnke-Emde. All the harmonics are delayed by an amount τ with respect to the fundamental. The terms $\sin(\theta + n\pi/2)$ are normally indeterminate. They depend not only on the unknown phase changes θ_1 and θ_2 but also on the precise electrical length of the feeder and the radio frequency. In a multi-repeater system, such terms would appear randomly phased, and hence would add up 'power-wise' from repeater to repeater. It is convenient, therefore, to give them their r.m.s. values of $1/\sqrt{2}$. But it should always be borne in mind that for any one particular set-up these terms will be quite definite, and can be, for example, zero for certain frequencies or lengths of feeder.

Accordingly we find

$$\frac{\text{2nd Harmonic}}{\text{Fundamental}} = \sqrt{2}\,r_1 r_2 e^{-2\alpha i}(2\omega_a/\Delta\omega)\mathrm{J}_2(y)$$

$$\frac{\text{3rd Harmonic}}{\text{Fundamental}} = \sqrt{2}\,r_1 r_2 e^{-2\alpha i}(3\omega_a/\Delta\omega)\,.\,\mathrm{J}_3(y) \quad (6)$$

$$\frac{n\text{th Harmonic}}{\text{Fundamental}} = \sqrt{2}\,r_1 r_2 e^{-2\alpha i}(n\omega_a/\Delta\omega)\mathrm{J}_n(y)$$

where $y = 2\Delta\omega\tau\,.\,\sin(\omega_a\tau)/\omega_a\tau$

To get the harmonic margins in decibels we simply take $20\log_{10}$ of the above expressions.

It is clear from equation (6) that the margins of the harmonics with respect to the fundamental depend on the modulating frequency ω_a. In many cases ω_a is small, so that $y \approx 2\Delta\omega\tau$ and the harmonics are proportional to the modulating frequency, ω_a. Also, the harmonics are all delayed by τ with respect to the recovered signal. Since τ is different for different repeater-stations, it follows that there can be no component of distortion adding up in phase from repeater to repeater, and there will be therefore no 'voltage-rise' component of third-harmonic distortion.

These properties of the distortion are different from those which arise when the signal output can be taken as a simple power series expansion of the input. It should not, therefore, be surprising if the absolute value of time delay variation with frequency should turn out not to be a suitable measure of the distortion.

For very short runs, y is small, and $J_2(y) \approx y^2/8$. Hence equation (5) gives, for the second harmonic

$$2r_1r_2\,e^{-2\alpha}\omega_a(\Delta\omega)^2\tau^2 \cdot [\sin(\omega_a\tau)/\omega_a\tau]^2 \sin(2\tau\omega_c - \theta_1 - \theta_2).$$

Apart from the absence of the factor $[\sin(\omega_a\tau)/\omega_a\tau]^2$ which is usually very close to 1, and the omission of θ_1 and θ_2, this is the same result as can be obtained from the formula for the phase given on p. 62 of Friis's paper (*loc cit.*) by the use of the first few terms of the quasi-stationary-state expansion. But the expression for the variation of time delay with frequency increases proportionally to the length of feeder no matter how long it may be, while $J_2(y)$ does not rise indefinitely as $y^2/8$, but reaches a maximum of about 0.486 at $y \approx 3$, whereafter it decreases again and oscillates about zero. For this reason, it is felt that the time-delay variation is not a suitable quantity to use when discussing the distortion arising from feeder mismatches unless the feeder is very short, and conclusions drawn about the unusability of very long feeders may not necessarily be sound.

Unless the feeder length is comparable with the wavelength of the modulating frequency ω_a, $\omega_a\tau$ will be small, and $\sin \omega_a\tau/\omega_a\tau$ can be replaced by unity. Hence $y \approx 2\Delta\omega\tau$. However, if $\omega_a\tau = \pi$, $y = 0$ and there is no harmonic distortion whatsoever. This is easily seen to be so from equation (1) since the second term is merely a small multiple of the first, which is accordingly transmitted without phase distortion. This phenomenon will not usually occur for more complex modulating signals, however.

5. Example

Consider a wave of r.f. carrier wavelength $\lambda = 7$ cm, conveyed over a feeder consisting of 50 ft of 2 in $\times \frac{3}{4}$ in brass waveguide. Let the peak frequency deviation of the modulation be 3 Mc/s, the video band being 800 kc/s wide. It is required to find the distortion at the top of the band. The voltage standing-wave ratios at the ends of the feeder will be taken as 0.95 and 0.65, and the attenuation along the guide as 1 db each way. The group velocity is $3 \times 10^{10} \cdot \sqrt{1 - \lambda^2/4a^2}$ with $a = 2$ in.

Hence $v = 2.1 \times 10^{10}$ cm/sec and $\tau = 0.71 \times 10^{-7}$ sec.

We use a modulating tone of frequency 0.4 Mc/s in order that its 2nd harmonic may be at the top of the band.

Then $\omega_a\tau = 2\pi \times 0.4 \times 0.071 = 0.178$ or 10°,

$$\sin(\omega_a\tau)/\omega_a\tau = 0.995$$

$$y = 2\Delta\omega\tau \cdot \sin(\omega_a\tau)/\omega_a\tau = 2.66. \quad J_2(y) = 0.46$$

$$r_1r_2 = \frac{1 - 0.95}{1 + 0.95} \cdot \frac{1 - 0.65}{1 + 0.65} = 5.4 \times 10^{-3}$$

$$\therefore \frac{\text{2nd Harmonic}}{\text{Fundamental}} = 5.4 \times 10^{-3} \times (0.8/3) \times 0.45 \times 10^{-0.1} \times \sqrt{2} \equiv 63 \text{ db}.$$

The ratio of third to second harmonic, when each in turn is arranged to occur at the top of the band (by a suitable choice of ω_a for each), is $J_3(2.66)/J_2(2.66) = 0.5$. The third is thus 6 db down on the second. Since $J_n(y)$ decreases for n greater than y, the higher harmonics rapidly become negligible in this example.

Thus $J_4(2.66)/J_2(2.66) = 0.17$ which is equivalent to a 15-db margin of fourth to second harmonic.

Equality of third to second would obtain for $y = 3.75$; i.e., for a length of about 70 ft in this example. For greater lengths the second harmonic drops rapidly, becoming zero at 100 ft, the third and subsequently the higher harmonics becoming dominant.

6. Connection between Cross-talk and Harmonics

This subject will be dealt with in detail in a forthcoming paper. However, it is obvious from the above example and from Section 4 that the variation of time delay is not a suitable measure of the amount of harmonics produced (except for very small feeder lengths), and it transpires that the harmonic production is equally unsuitable (except in the case of the preponderance of second and third) to describe the cross-talk.

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FEEDBACK AMPLIFIERS AND SERVO SYSTEMS

Their Common Theoretical Basis

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1. Introduction

THIS paper, by drawing attention to certain relationships, seeks to show that the distinction between frequency response and transient response which was inevitable in the history of amplifiers and servo systems now threatens to distract attention from facts which are more fundamental—namely, the pattern of poles and zeros of the response function. This pattern might afford a useful basis for classifying and studying these devices since it avoids any cleavage between the frequency function and time function points of view and it appears possible by using the Laplace Transform to sketch out a broader theory which includes them both as special cases. Arguments which hold for feedback amplifiers are in many cases equally true for servo systems since the basic principles of these two devices are alike. The analysis which follows can therefore be applied to both ; it will be restricted to linear systems having lumped constants and one closed loop and will be seen to be indebted to the writings of Dr. K. W. Wagner. It is hoped that it will serve as a basis for the extensions and corrections which others will be able to suggest.

2. Two Points of View

2.1 *The Transient Analysis*

In negative-feedback amplifiers which meet the conditions stated above, and also similarly in servo systems, having an output voltage E_0 and transmitting an input voltage E_i, the relations between these quantities may be stated by an equation such as :

$$\left(m_0 + m_1 \frac{d}{dt} + m_2 \frac{d^2}{dt^2} + \ldots\right) E_0 = \left(n_0 + n_1 \frac{d}{dt} + n_2 \frac{d}{dt^2} + \ldots\right) E_i$$

This is a linear equation with constant coefficients which may be abbreviated as

$$f_1(D)E_0 = f_2(D)E_i$$

and which may be solved for the transient oscillation by the familiar substitution $E_0 = Ke^{st}$ in which s may have to be complex. Putting $s = u + jv$ the output voltage will be the sum of a number of terms and will have the form

$$E_0 = \Sigma K e^{ut + jvt}$$

The important point for our present purpose is that this well-known result is similar to the notation whereby an oscillating quantity of angular frequency ω is commonly written as the real part of $Ke^{j\omega t}$ and, in fact, if the coefficients of the equations were such as to represent a system of zero loss and damping, the term u would vanish in the solution, which would represent a steadily oscillating response of the form $Ke^{j\omega t}$.

2.2 *The Frequency Analysis.*

This treatment, unlike that given above, concentrates on the performance of the system under sinusoidal signals. For an input oscillation E_i having an angular frequency ω at which the forward and feedback chains have amplifications μ and β respectively, the output oscillation will be : $E_0 = \left(\frac{\mu}{1 + \mu\beta}\right) E_i$

In this equation all the terms may be complex : the response of the system, defined as the Transfer Function Y, or the complex quotient E_0/E_i is found by working out the modulus and argument of the expression in brackets ; the design methods based on the Nyquist diagram demand not only a knowledge of the values of the complex quantity $\mu\beta$ but an ability to control its variation as a function of ω in the manner required.

Here is the crux of the matter for the designer. His task is to obtain effective design control over the modulus and argument of the product $\mu\beta$. If we take G_1 to be the loop gain in nepers and ϕ_1 the loop phase shift in radians then

$$\log(\mu\beta) = \log|\mu\beta| + j \operatorname{Arg}(\mu\beta) = G_1 + j\phi_1$$

The practical difficulty is that G_1 and ϕ_1 are not independent ; with a few exceptions, a change in one must affect the other ; their inter-dependence is, in most practical systems, of a complicated and elusive kind.

The principle which governs this inter-dependence is, however, not a complicated one and is best understood by starting with a simple case such as the circuit shown in Fig. 1. If an input

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voltage $E_i\sqrt{2}\sin\omega t$ be applied to this circuit in which the inductance is L and the resistance R then the open-circuit voltage E_0 at the output terminals is given by

$$E_0 = \left(\frac{R}{R + j\omega L}\right) E_i \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

and if the response be written as

$$\frac{E_0}{E_i} = |Y|e^{j\phi} \text{ with } \frac{R}{L} = \omega_0 \text{ then}$$

$$|Y| = \frac{\omega_0}{\sqrt{\omega_0^2 + \omega^2}}; \quad \phi = -\tan^{-1}\left(\frac{\omega}{\omega_0}\right)$$

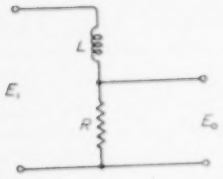


Fig. 1 (above). *Circuit represented by Equ.* (1).

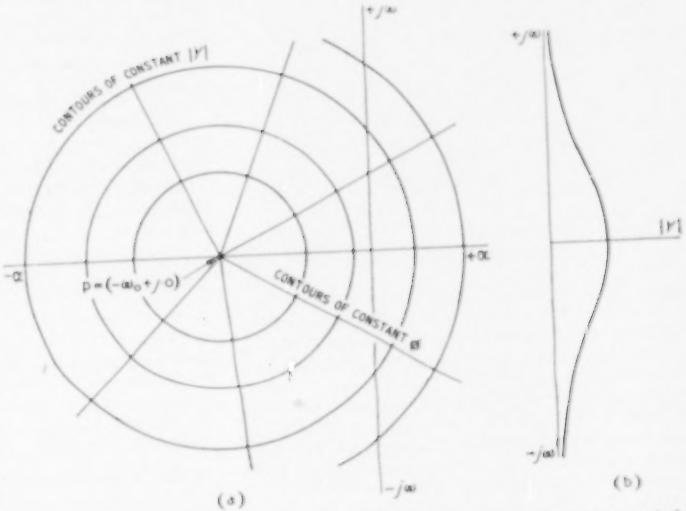


Fig. 2 (right). *Pole of a response function* (a), *and the variation of* $|Y|$ *along the* $j\omega$ *axis* (b).

In this form as functions of ω the above expressions for $|Y|$ and ϕ do not suggest that they are related in any simple way. However, if we write $E_i\sqrt{2}\sin\omega t$ as the real part of $E_i\sqrt{2}e^{j\omega t}$ and regard $j\omega$ as the imaginary term of a complex variable $(\alpha + j\omega)$ then we have

$$|Y| = \frac{\omega_0}{\sqrt{(\omega_0 + \alpha)^2 + \omega^2}}$$

$$\phi = -\tan^{-1}\left(\frac{\omega}{\omega_0 + \alpha}\right)$$

If contours of constant $|Y|$ and ϕ be plotted in the plane of $(\alpha + j\omega)$ they appear as concentric circles and as radii respectively, disposed as in Fig. 2(a) about a centre at $(\alpha = -\omega_0, j\omega = 0)$. Equation (1) which, in this complex plane, has a meaning only on the $j\omega$ axis, may be rewritten as

$$E_0 = \left[\frac{R}{R + (\alpha + j\omega)L}\right] E_i$$

$$\text{or } E_0 = \left[\frac{\omega_0}{\omega_0 + p}\right] E_i \quad \ldots \quad (2)$$

where p is the complex quantity $p = \alpha + j\omega$. Equation (2) shows that the quotient $\left(\frac{E_0}{E_i}\right)$ has a pole (i.e., it tends to infinity) at $p = (-\omega_0 + j.0)$ and this simple example shows that the obscure connection between $|Y|$ and ϕ as found by sine-wave measurements (that is, on the $j\omega$ axis where $\alpha = 0$) is that they are both obliged to vary in the manner determined by the pole of the response function. This pole is not to be found on the $j\omega$ axis but is at the point $p = (-\omega_0 + j.0)$ in the complex plane. This is shown in Fig. 3 where the height of the solid figures represents $|Y|$. The value of $|Y|$ for sine waves, for which $\alpha = 0$, is represented by the section cut in the solid figure by the plane containing the $j\omega$ axis and this section is shown in Fig. 2(b).

Finally, by taking logarithms, we have

$$N = G + j\phi = \log\{|Y|e^{j\phi}\} = \log\{f(\alpha + j\omega)\}$$

which is the fundamental relation between gain and phase, showing them to be conjugate functions of the complex variable $(\alpha + j\omega)$. This means that G, the gain in nepers, and ϕ, the phase rotation in radians, are real quantities which are free to vary only in certain inter-dependent ways; their mutual relation must be such that the complex variable $N = (G + j\phi)$ will always have a finite differential coefficient with respect to the complex variable $p = (\alpha + j\omega)$ of which it will be an analytic function. Contours of constant G and of constant ϕ will then intersect orthogonally when mapped in the plane of $(\alpha + j\omega)$. Although the above example is a simple one it will appear later that the gain and phase of more complicated structures having several poles and zeros are, with certain exceptions, related in a closely

similar manner when regarded as functions of $(\alpha + j\omega)$.

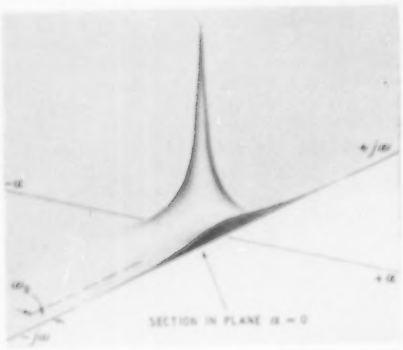


Fig. 1. *This solid figure represents the contours of Fig. 2(a).*

3. Pattern of Poles and Zeros §

We can therefore see that the exponential way of representing an oscillation as $Ae^{j\omega t}$ may usefully be extended as $Ae^{(\alpha+j\omega)t}$ and that this latter form not only represents the possible responses to a transient but also brings to light the underlying reasons for behaviour which is observed under sinusoidal signals and represented along the $j\omega$ axis. The handy name Complex Frequency has quite wrongly crept into use for the variable $p = (\alpha + j\omega)$ and needs attention from those who watch over our nomenclature. The idea itself, however, is clearly important and we must now show how it can be used.

The instance taken above shows how the response $\left(\frac{\omega_0}{\omega_0 + j\omega}\right)$ to an oscillation $Ae^{j\omega t}$ becomes $\left(\frac{\omega_0}{\omega_0 + (\alpha + j\omega)}\right)$ to an oscillation $Ae^{(\alpha+j\omega)t}$ and in general the transfer function of a complicated system may be written as

$$|Y|e^{j\phi} = \left(\frac{E_0}{E_i}\right) = \left[\frac{(p+a_1)(p+a_2)(\ldots}{(p+b_1)(p+b_2)(\ldots}\right] \qquad (3)$$

a quotient which has poles at $-b_1$, $-b_2$ etc., and zeros at $-a_1$, $-a_2$, etc., where some of the a and b terms may be real and some complex; since the coefficients are real, complex roots will appear only in conjugate pairs. The modulus and argument of $|Y|e^{j\phi}$ vary from point to point in the plane of $p = \alpha + j\omega$ and depend only on the positions of the poles and zeros of the function. When the transfer function is extended in this way to have a meaning for signals of the form $Ae^{(\alpha+j\omega)t}$ it is called a Laplace Transform.

An impedance or admittance which is a function of the variable $j\omega$ may similarly be extended as a function of $(\alpha + j\omega)$. For example, if the current in an inductance be $Ie^{j\omega t}$ then the product Ldi/dt will have the value $LIj\omega e^{j\omega t}$ giving an impedance $j\omega L$; whereas if the current be $Ie^{(\alpha+j\omega)t}$ then Ldi/dt will become $LI(\alpha + j\omega)e^{(\alpha+j\omega)t}$ giving an impedance $(\alpha + j\omega)L$ which is again a Laplace Transform.

From this point we can see how the frequency performance and the transient performance of a feedback amplifier or a servo-system can be built up from the pattern of poles and zeros of the response function.

3.1 *Performance as a Frequency Function :*

For simplicity we may allow ourselves to speak of the poles and zeros of a system when strictly we mean that they belong to an equation. Thus we say that a system having a single pole at $\alpha = -\omega_0$ will have a transfer function

$$Y_{(p)} = \left(\frac{\omega_0}{p + \omega_0}\right)$$

and for sinusoidal oscillations

$$Y_{(j\omega)} = \left(\frac{\omega_0}{j\omega + \omega_0}\right)$$

of which we have already found the modulus and argument. Likewise, for a system of two poles :

$$Y_{(j\omega)} = \frac{a_1}{(j\omega + b_1)\ (j\omega + b_2)}$$

In the general case, the modulus and argument of the response are the values given by the Laplace Transform when p is purely imaginary; from Equ. (3) these are :

$$|Y|_{(j\omega)} = \left|\frac{E_0}{E_i}\right| = \left\{\frac{|j\omega+a_1| \times |j\omega+a_2| \times \ldots}{|j\omega+b_1| \times |j\omega+b_2| \times \ldots}\right\}$$

$$\phi_{(j\omega)} = \mathrm{Arg}E_0 - \mathrm{Arg}E_i = \Sigma\mathrm{Arg}(j\omega + a_n) - \Sigma\mathrm{Arg}(j\omega + b_n)$$

and the gain of the system may be found by adding algebraically the components due to each pole and zero :

$$G = \log|Y| = \Sigma\log|j\omega + a_n| - \Sigma\log|j\omega + b_n|$$

The poles of the transfer function of equation (3) are the zeros of the function $(1 + \mu\beta)$ and a convenient practical technique at present in use consists in applying the above analysis to the product $\mu\beta$ which is similarly a rational function of p and of which G_1 and ϕ_1 may be displayed in a Nyquist diagram as functions of $j\omega$.

3.2 *Response to a Transient*

The importance of the complex variable $p = (\alpha + j\omega)$ in predicting the response to a

§ See, for example : E. G. Phillips : "Functions of a Complex Variable"; Oliver & Boyd, 1947.

transient is a result of the difficulty of representing a transient in mathematical terms. Repeating oscillations of complicated shapes may be represented by Fourier series, consisting of terms of the form $Ae^{j\omega t}$, but however small the angular frequency ω may be, the oscillations go on indefinitely whereas a transient happens only once. This is not surprising since the Fourier series contain no mechanism to provide for the dying away of the components which form the sum. Of the several possible devices, that used in the Laplace Transform consists in assembling the transient from the 'terms' of a Fourier integral—that is, a Fourier series having its terms infinitely close together in frequency—of which the 'terms' are multiplied by a decay factor $e^{\alpha t}$. The transient is therefore assembled from oscillations of the form $Ae^{\alpha+j\omega t}$.

The magnitude of any chosen component $Ae^{j\omega t}$ of a Fourier series is found by integrating over one cycle the product of the time function $f(t)$ and a multiplier $e^{-j\omega t}$ which holds the required term constant while the other terms perform complete cycles of which the integrals vanish. Similarly the magnitude (more precisely, the complex amplitude function) of any chosen component $A.dp.e^{\alpha+j\omega t}$ of the Laplace Transform is found by integrating over one cycle (there is only one; i.e., from $t=0$ to $t=+\infty$) the product $f(t) \times e^{-\alpha+j\omega t} = f(t)\, e^{-pt}$. If the transform exists, the real part of p must not fall below a certain value, known as the Abscissa of Convergence, in order to make the integral convergent. As in a Fourier series, the integral $\int_0^\infty f(t).e^{-pt}.dt$ answers the question, "How strong is the component oscillation of the form $e^{pt}dp$?" and the answer it gives depends, of course, on the value of p in the question. This means that for a given transient input signal E_i the Laplace Transform is a function which shows the strength in that particular transient of the component oscillations of form $e^{pt}dp$ and the manner in which it depends on p and K. W. Wagner has clinched the matter by calling it the Frequency Spectrum of the transient.[†]

We are now within sight of our goal. For we have already seen that an impedance function or a response function of an electrical system—and, equally, of a mechanical system—to oscillations of precisely this form is a function of its poles and zeros in the plane of p and is also known as a Laplace Transform. The output signal of the system will, therefore, consist of a spectrum of incremental oscillations, each of the form $A.dp.e^{\alpha+j\omega t}$, where for every value of p the coefficient A will be the product of the strength of that oscillation in the original signal (i.e., $\mathfrak{L}E_i$) and the amplification or attenuation and phase-shift applied to it by the system (i.e., $Y_{(p)}$). In order to find the output we have to add these oscillations.

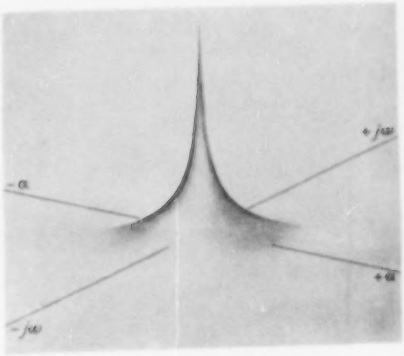


Fig. 4. *Laplace transform of a step function: the amplitude of any given component is represented by the height of the solid figure.*

A concrete example will help here and we may attempt the response of an elementary amplifier or servo system having a second-order equation and subject to a step-function. Using the symbols $\mathbf{1}E_i$ to represent the step-function we know that its 'frequency spectrum' or Laplace Transform is $\mathfrak{L}\mathbf{1}E_i = E_i/p$ meaning that the incremental oscillations lying between e^{pt} and e^{p+dpt} have a complex amplitude $(E_i\, dp)/p$. This function has a simple pole at the origin and is otherwise analytic. It is shown graphically in Fig. 4. The transfer function of the system for oscillations Ae^{pt} will be

$$Y_{(p)} = \left(\frac{E_0}{E_i}_{(p)}\right) = \frac{F^2}{p^2 + 2Kp + F^2}$$

and the 'frequency spectrum' of the output oscillations will therefore be

$$\mathfrak{L}E_0 = \left(\frac{F^2}{p^2 + 2Kp + F^2}\right).\frac{E_i}{p}$$

which may be factorised as

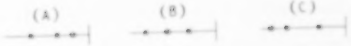
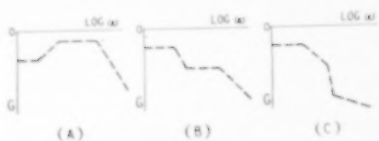
$$\mathfrak{L}E_0 = \left(\frac{F^2}{p(p + b_1)(p + b_2)}\right) E_i \quad .. \quad (4)$$

One of the possible dispositions of this output transform is shown graphically in Fig. 5. The output is given by adding all the oscillations whose amplitudes are shown in Fig. 5, along the line from $c - j\infty$ to $c + j\infty$, the real part α being held to a certain minimum value c as will appear later.

The process of adding these oscillations, that is, of integrating a function of a complex variable,

† "Operatorenrechnung": p. 28: Leipzig, 1940.

TENTATIVE CLASSIFICATION

	ONE REAL POLE	TWO REAL POLES
NO ZERO (a)		
(b)	$Y = \frac{1}{(p + b_1)}$	$Y = \frac{1}{(p + b_1)(p + b_2)}$
(c)	$Y = \frac{1}{(j\omega + b_1)}$	$Y = \frac{1}{(j\omega + b_1)(j\omega + b_2)}$
(d)	$\log\|Y\| = -\left\{\log b_1 + \log\left\|1 + \frac{j\omega}{b_1}\right\|\right\}$	$\log\|Y\| = -\left\{\log b_1 b_2 + \log\left\|1 + \frac{j\omega}{b_1}\right\| + \log\left\|1 + \frac{j\omega}{b_2}\right\|\right\}$
(e)	$\text{Arg } Y = -\tan^{-1}\left(\frac{\omega}{b_1}\right)$	$\text{Arg } Y = -\left\{\tan^{-1}\left(\frac{\omega}{b_1}\right) + \tan^{-1}\left(\frac{\omega}{b_2}\right)\right\}$
(f)	$f_{(t)} = A_1(1 - e^{-b_1 t})$	$f_{(t)} = A_1 + A_2 e^{-b_1 t} + A_3 e^{-b_2 t}$
(g)		
ONE ZERO (a)		
(b)	$Y = \frac{(p + a_1)}{(p + b_1)}$	$Y = \frac{(p + a_1)}{(p + b_1)(p + b_2)}$
(c)	$Y = \frac{(j\omega + a_1)}{(j\omega + b_1)}$	$Y = \frac{(j\omega + a_1)}{(j\omega + b_1)(j\omega + b_2)}$
(d)	$\log\|Y\| = \left[\log a_1 + \log\left\|1 + \frac{j\omega}{a_1}\right\|\right] - \left[\log b_1 + \log\left\|1 + \frac{j\omega}{b_1}\right\|\right]$	$\log\|Y\| = \left\{\log a_1 + \log\left\|1 + \frac{j\omega}{a_1}\right\| - \left\{\log b_1 b_2 + \log\left\|1 + \frac{j\omega}{b_1}\right\| + \log\left\|1 + \frac{j\omega}{b_2}\right\|\right\}\right.$
(e)	$\text{Arg } Y = \tan^{-1}\left(\frac{\omega}{a_1}\right) - \tan^{-1}\left(\frac{\omega}{b_1}\right)$	$\text{Arg } Y = \tan^{-1}\left(\frac{\omega}{a_1}\right) - \tan^{-1}\left(\frac{\omega}{b_1}\right) - \tan^{-1}\left(\frac{\omega}{b_2}\right)$
(f)	$f_{(t)} = A_1 - A_2 e^{-b_1 t}$	$f_{(t)} = A_1 + A_2 e^{-b_1 t} + A_3 e^{-b_2 t}$
(g)		

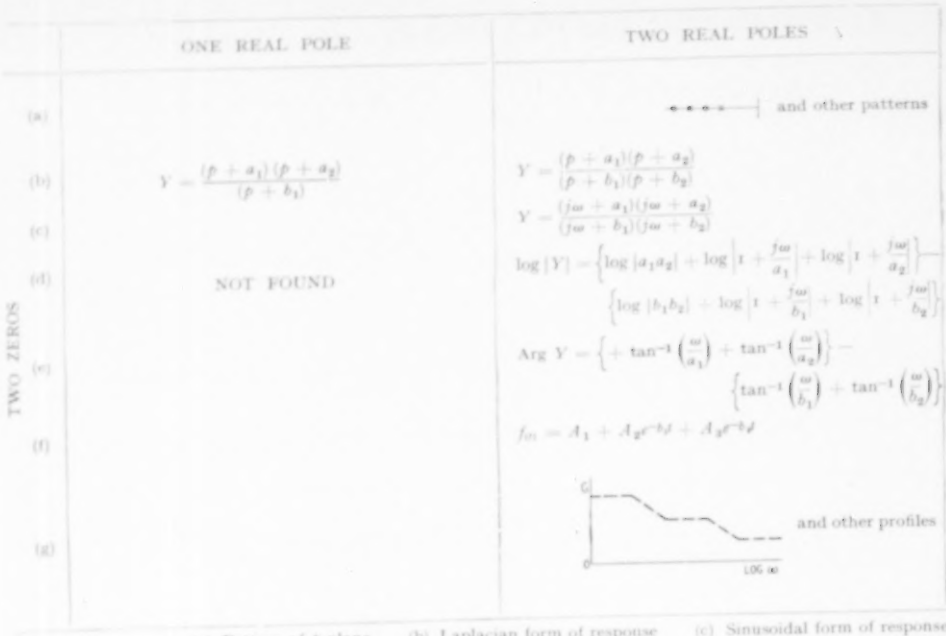
(a) Pattern of p-plane (b) Laplacian form of response (c) Sinusoidal form of response

OF RESPONSE FUNCTIONS

TWO COINCIDENT POLES	TWO COMPLEX POLES	
		(a)
$Y = \frac{1}{(p + b_1)^2}$	$Y = \frac{1}{[p + (\alpha_0 + j\omega_0)][p + (\alpha_0 - j\omega_0)]}$	(b)
$Y = \frac{1}{(j\omega + b_1)^2}$	$Y = \frac{1}{[-\omega^2 + 2j\omega\alpha_0 + (\alpha_0^2 + \omega_0^2)]}$	(c)
$\log \lvert Y \rvert = -2\left\{\log b_1 + \log\left\lvert 1 + \frac{j\omega}{b_1}\right\rvert\right\}$	$\log \lvert Y \rvert = -\log\lvert(\omega_0^2 + \alpha_0^2 - \omega^2) + 2j\omega\alpha_0\rvert$	(d)
$\text{Arg } Y = -2\tan^{-1}\left(\frac{\omega}{b_1}\right)$	$\text{Arg } Y = -\tan^{-1}\left(\frac{2\omega\alpha_0}{\alpha_0^2 + \omega_0^2 - \omega^2}\right)$	(e)
$f_{(t)} = A_1[1 - (1 + b_1 t)e^{-b_1 t}]$	$f_{(t)} = A_1 + A_2 e^{-\alpha_0 t}\sin(\omega_0 t + A_3)$	(f)
		(g)

		(a)
$Y = \frac{(p + a_1)}{(p + b_1)^2}$	$Y = \frac{(p + a_1)}{[p + (\alpha_0 + j\omega_0)][p + (\alpha_0 - j\omega_0)]}$	(b)
$Y = \frac{(j\omega + a_1)}{(j\omega + b_1)^2}$	$Y = \frac{(j\omega + a_1)}{[-\omega^2 + 2j\omega\alpha_0 + (\alpha_0^2 + \omega_0^2)]}$	(c)
$\log \lvert Y \rvert = \left\{\log a_1 + \log\left\lvert 1 + \frac{j\omega}{a_1}\right\rvert\right\} - 2\left\{\log b_1 + \log\left\lvert 1 + \frac{j\omega}{b_1}\right\rvert\right\}$	$\log \lvert Y \rvert = \log a_1 + \log\left\lvert 1 + \frac{j\omega}{a_1}\right\rvert - \log\lvert(\omega_0^2 + \alpha_0^2 - \omega^2) + 2j\omega\alpha_0\rvert$	(d)
$\text{Arg } Y = \tan^{-1}\left(\frac{\omega}{a_1}\right) - 2\tan^{-1}\left(\frac{\omega}{b_1}\right)$	$\text{Arg } Y = \tan^{-1}\left(\frac{\omega}{a_1}\right) - \tan^{-1}\left(\frac{2\omega\alpha_0}{\alpha_0^2 + \omega_0^2 - \omega^2}\right)$	(e)
$f_{(t)} = A_1 + (A_2 t - A_1)e^{-b_1 t}$	$f_{(t)} = A_1 + A_2 e^{-\alpha_0 t}\sin(\omega_0 t + A_3)$	(f)
		(g)

(d) Gain (e) Phase (f) Step-function response (g) Gain profiles


ONE REAL POLE
TWO REAL POLES
TWO ZEROS
(a)
(b)
(c)
(d)
(e)
(f)
(g)
and other patterns
$Y = \frac{(p + a_1)(p + a_2)}{(p + b_1)}$
$Y = \frac{(p + a_1)(p + a_2)}{(p + b_1)(p + b_2)}$
$Y = \frac{(j\omega + a_1)(j\omega + a_2)}{(j\omega + b_1)(j\omega + b_2)}$
NOT FOUND
$\log |Y| = \left\{\log |a_1 a_2| + \log \left|1 + \frac{j\omega}{a_1}\right| + \log \left|1 + \frac{j\omega}{a_2}\right|\right\} -$
$\left\{\log |b_1 b_2| + \log \left|1 + \frac{j\omega}{b_1}\right| + \log \left|1 + \frac{j\omega}{b_2}\right|\right\}$
$\text{Arg } Y = \left\{+ \tan^{-1}\left(\frac{\omega}{a_1}\right) + \tan^{-1}\left(\frac{\omega}{a_2}\right)\right\} -$
$\left\{\tan^{-1}\left(\frac{\omega}{b_1}\right) + \tan^{-1}\left(\frac{\omega}{b_2}\right)\right\}$
$f_{(t)} = A_1 + A_2 e^{-b_1 t} + A_3 e^{-b_2 t}$
G
0
LOG ω
and other profiles

(a) Pattern of p-plane (b) Laplacian form of response (c) Sinusoidal form of response

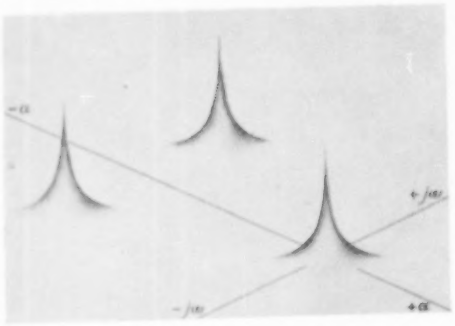


Fig. 5. *Laplace transform of output.*

s almost impossible to grasp without some kind of physical analogue ; perhaps the most graphic of these is a large shallow sink provided with a plug-hole at each zero of the plane and a running tap at each pole. The function of equation (4) has one pole at the origin and two other poles which may be disposed in certain ways in the negative half plane. The integral for $t < 0$ is taken over the positive half plane ; the hydraulic analogy is in agreement in that the total flow over a closed contour which does not enclose either sources or sinks is zero. The integral for $t > 0$ is taken over the negative half plane in the manner shown in Fig. 6 and the constant value of $\alpha = c$ is taken to ensure that all the poles and zeros—corresponding to sources and sinks—are enclosed. Analytically, the integral is written

$$E_0 = \frac{1}{2\pi j}\int_{c-j\infty}^{c+j\infty} \frac{E_i \cdot F^2 e^{pt}}{p(p + b_1)(p + b_2)} \cdot dp$$

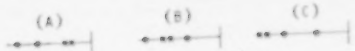
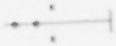
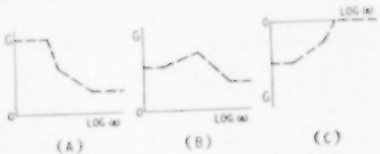
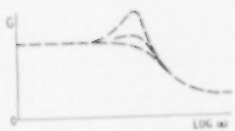
$$= \frac{E_i}{2\pi j}\int_{c-j\infty}^{c+j\infty} e^{pt}\left[\frac{F_1}{p} + \frac{F_2}{(p + b_1)} + \frac{F_3}{(p + b_2)}\right] \cdot dp$$

and the familiar result is seen to contain a characteristic contribution from each pole or pair of conjugate poles of the response function. The final form of the output is governed by the values of b_1 and b_2 but one possible response is given by

$$E_0 = E_i\left\{1 - K_1 e^{b_1 t} + K_2 e^{b_2 t}\right\}$$

4. Tentative Classification

Without attempting a rigorous mathematical proof, we have shown that poles and zeros of a rational function are the only elements available for building the response functions of such systems as we are examining. It is therefore

TWO COINCIDENT POLES	TWO COMPLEX POLES	
		(a)
$Y = \frac{(p + a_1)(p + a_2)}{(p + b_1)^2}$	$Y = \frac{(p + a_1)(p + a_2)}{[p + (\alpha_0 + j\omega_0)][p + (\alpha_0 - j\omega_0)]}$	(b)
$Y = \frac{(j\omega + a_1)(j\omega + a_2)}{(j\omega + b_1)^2}$	$Y = \frac{(j\omega + a_1)(j\omega + a_2)}{[(-\omega^2 + 2j\omega\alpha_0 + (\alpha_0^2 + \omega_0^2)]}$	(c)
$\log\lvert Y\rvert = \left\{\log\lvert a_1 a_2\rvert + \log\left\lvert 1 + \frac{j\omega}{a_1}\right\rvert + \log\left\lvert 1 + \frac{j\omega}{a_2}\right\rvert\right\} - 2\left\{\log b_1 + \log\left\lvert 1 + \frac{j\omega}{b_1}\right\rvert\right\}$	$\log\lvert Y\rvert = \left\{\log a_1 a_2 + \log\left\lvert 1 + \frac{j\omega}{a_1}\right\rvert + \log\left\lvert 1 + \frac{j\omega}{a_2}\right\rvert - \log\lvert(\omega_0^2 + \alpha_0^2 - \omega^2) + 2j\omega\alpha_0\rvert\right\}$	(d)
$\text{Arg } Y = \left\{+ \tan^{-1}\left(\frac{\omega}{a_1}\right) + \tan^{-1}\left(\frac{\omega}{a_2}\right) - 2\tan^{-1}\left(\frac{\omega}{b_1}\right)\right\}$	$\text{Arg } Y = \left\{\tan^{-1}\left(\frac{\omega}{a_1}\right) + \tan^{-1}\left(\frac{\omega}{a_2}\right) - \tan^{-1}\left(\frac{2\omega\alpha_0}{\alpha_0^2 + \omega_0^2 - \omega^2}\right)\right\}$	(e)
$f_{(t)} = A_1 + (A_2 t + A_3)e^{-b_1 t}$	$f_{(t)} = A_1 + A_2 e^{-\alpha t}\sin(\omega_0 t + A_3)$	(f)
		(g)

(d) Gain (e) Phase (f) Step-function response (g) Gain profiles

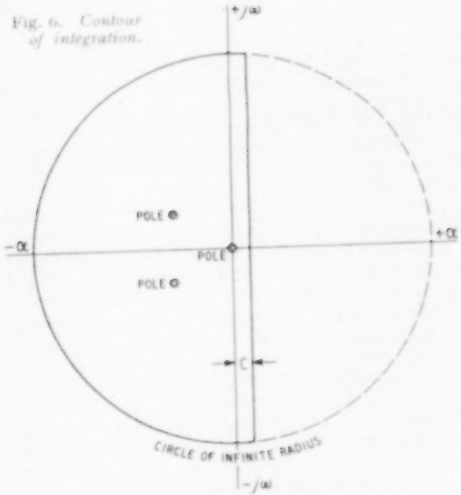


Fig. 6. *Contour of integration.*

clear that—with certain exceptions—a given trio of gain, phase and transient functions, generated by a given pattern of poles and zeros, can only make a joint appearance and will not be found in other arrangements. Thus the pattern of the singularities in the p-plane is a logical basis for classifying these systems and the summary of known results which appears in the accompanying Table should make it possible to estimate the uses and limitations of the scheme and to extend it. The response functions met in real amplifiers and servo systems are usually more complicated than any shown in the Table but their gain, phase and transient responses may all be assembled from those elements which are shown.

The next task in integrating the theory of linear closed-loop systems is to show how to provide a computing device whereby the gain, phase and transient functions may be given immediately in terms of the singularities in the complex plane. Work is now under way on such a device, following the lines sketched above.

5. Acknowledgment

The author wishes to acknowledge his debt to the interest and encouragement of Prof. A. Tustin and of his other colleagues in the Electrical Engineering Department of the University of Birmingham.

IMPEDANCE MEASUREMENT

Comparison Method with C. R. Indicator

By H. J. Round

A SIMPLE method of determining impedance and admittance values over ranges of frequency from 1,000 c/s to 150,000 c/s and impedance values from two or three ohms up to two or three hundred ohms is described. It was used at certain Naval Establishments during the war because beat-frequency oscillators (b.f.o.) and normal cathode-ray oscilloscopes (c.r.o.) with attached amplifiers were available. Being earthy instruments they did not lend themselves easily to bridge schemes without the introduction of carefully arranged transformers. It was consequently decided to try out a comparison method.

General Principle

The general principle employed is to establish a constant-current condition from the b.f.o. and for small currents this is done by using a swamping resistance, of about 100 times the value of the unknown impedance in series with it. The c.r.o. is then used as a voltage indicator to compare and equalize the voltages across the impedance and an adjustable resistance when these are placed in turn in series with the swamping resistance. The balancing resistance used is obtained from an ordinary non-inductive resistance box and Fig. 1 shows the simple arrangement in which the double-throw switch S enables one to set the resistance value in the box to give the same deflection on the c.r.o. as the unknown impedance. A big deflection on the c.r.o. is obviously a requirement for accuracy and the c.r.o. amplifier can be adjusted at will to keep deflection large. Voltage supply from the b.f.o. can also be varied according to requirements.

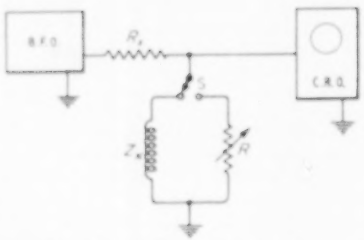


Fig. 1. *General arrangement of comparison method: R_s is the swamping resistance to give constant current, Z_x the unknown impedance and R a resistance box.*

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It will be seen that one has now obtained a resistance value R equal to the scalar value of the impedance and that the vector angle is still unknown. If now a known impedance, say either a resistance R'' or a reactance, is connected with the unknown, either in series or in parallel, and a new balancing value of resistance R' determined sufficient data is obtained to evaluate the vector angle graphically or by calculation. Fig. 2 shows the addition of a known resistance R'' in series with the unknown impedance.

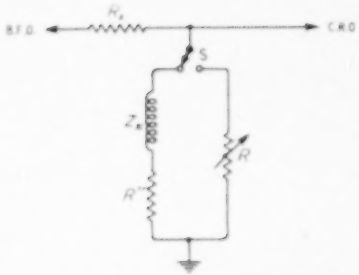


Fig. 2. *A second measurement with the addition of R'' enables the phase angle of Z_x to be determined.*

Details of Method

Consider the measurement of an inductive reactance such as a coil wrapped round a ferromagnetic core.

Suppose Z_x in Fig. 1 represents such a coil; the first measurement gives the scalar value R of the impedance of Z_x and all that can be stated is that the vector end lies somewhere on the circle A of radius equal to the impedance Z_x; that is, of radius equal to the balancing resistance R as in Fig. 3(a). OX and OY represent the resistive and reactive axes respectively.

The resistance R'' of about equal value to the impedance Z_x is now connected in series with the unknown and a new balancing-resistance value R' obtained. This enables us to draw a second circle A' of radius R' Fig. 3(b).

To see clearly what is happening let us suppose OV represents the actual vector of Z_x. To this we have added resistance R'' and in Fig. 3(b) this resistance is shown as VV'. The combined vector is now shown as OV'. If we draw a line

VO′ parallel to V′O then OO′ will also represent the added resistance R'' and O′V will also equal the combined vector.

It is easy now to see the construction to use Fig. 3(c). The first circle is struck with radius R, then OO′ is set out on the X axis negatively from O and equal to R'', and finally a new circle is struck with centre O′ with radius R' cutting the first circle at V and V_1.

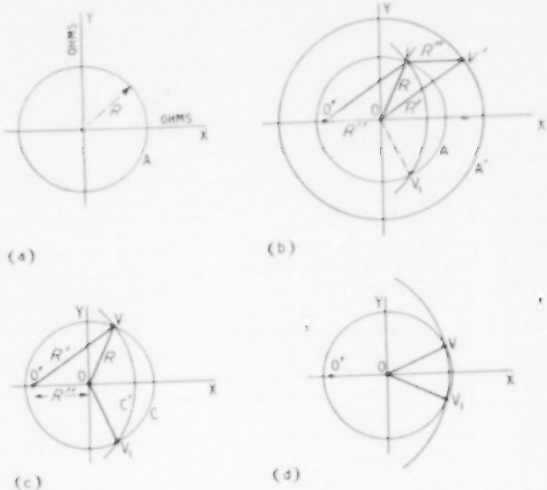


Fig. 3. *A single measurement, giving the magnitude of Z_x as R, enables only the circle A to be drawn as in (a). A second measurement with R'' added provides a second circle A′ as in (b), and then the vector OV can be determined. The construction to find the vector is shown in (c) while the difficulty which occurs when Z_x has a large resistive component is illustrated in (d).*

Quite definitely we can now say that the unknown is either OV or OV_1, usually other knowledge of the unknown will enable one to pick the right one of these two solutions. It will be noted that no calculations are necessary, a pair of compasses and some graph paper being the only requirements.

Improved Method

Experience with this method very soon showed up serious faults.

If R'' is chosen as a rather small value the cutting angle of the two circles is very acute and point V is not very well defined. If R'' is chosen as a large value it will be easily seen that there is a possible greater error in the reading of O′V—again making V difficult to determine accurately.

Reactances with large resistive values give very indeterminate readings owing to the narrow cutting angles of the two circles, a case of this is illustrated in Fig. 3(d). The method was then revised and instead of inserting a known resistance R'' a known high-quality mica capacitor C, of impedance value approximately the same as the unknown, was inserted as shown in Fig. 4.

The construction of the diagram Fig. 5 is very similar but now the point O′ is marked off on the vertical axis, with OO′ equal to the added capacitive reactance. It will be seen in Fig. 5 that the cutting angle of the two circles A and A′ is a very good one for defining point V, right up to the point where V may be on the X axis.

The assumption is made of course that the mica capacitor is practically lossless.

An examination of Fig. 5 shows that for determining vectors which are capacitive, an added inductance of low loss is advisable to maintain a good cutting angle but the use of an added inductance was not developed very far as most of the measurements required were obtainable with added capacitors.

The two arcs A″ and A‴ show how the circle cutting angle decreases as the vector O′V increases until in the case of A‴ considerable error could be introduced. Here obviously if the point O″ were chosen as the centre of the second circle the cutting angle would be good. OO″ represents the addition of an inductance.

Apparatus

Switching

A switching system was evolved which is shown basically in Fig. 6 with the switches marked S_1 to S_4.

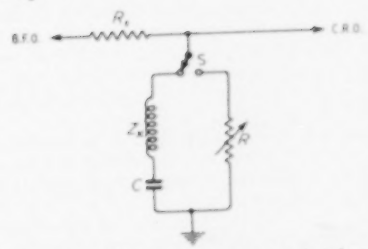


Fig. 4. *Here the second measurement is taken with a capacitance C inserted in series with Z_x.*

S_1 = double-pole double-throw switch for comparison purposes.

S_2 = double-pole single-throw switch to put the unknown in position for measuring.

S_3 = double-pole single-throw switch to insert the capacitor for setting and measurement.

S_4 = double-pole single-throw switch for inserting the capacitor in series with the unknown for the second vector measurement.

Operation

Using S_1 for comparison.

With S_2 thrown, the scalar value R is determined.

With S_3 thrown a capacitor is chosen with a scalar value R'' about equal to R or Z_x.

With S_4 thrown the combined scalar value R' is obtained.

On the graph sheet the position of the vector can then be at once marked.

It will be noted that the exact value of the capacitor need not be known as its reactance is determined in the operation with S_3.

It is nearly always most convenient to make the reactance of C equal to the unknown impedance; i.e., to R. This in general gives the best cutting angle and also speeds up the measurement.

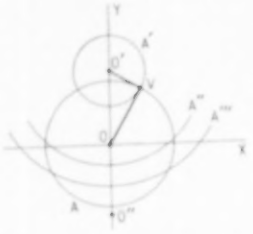


Fig. 5. *The construction to determine the vector when capacitance is added is shown.*

Notes on Measurements

If the impedance being measured is not very resistive the second circle is small in diameter and the c.r.o. deflection will on the same scale be small and difficult to read accurately. This can be countered in the measurement by either increasing the b.f.o. voltage or increasing the c.r.o. amplification. In fact, the tendency is always to work to a large fixed deflection marked on the c.r.o. tube. Incidentally waveform can be watched during the operations, and if this gets seriously away from a sine wave, filters can be inserted, unless, of course, the non-linearity is caused by the unknown.

Actually a simple capacitor to earth, connected part of the way along the swamping resistance from the b.f.o., can be made to provide sufficient filtering of harmonics.

A little later on the question of admittance measurement is discussed, and it is sometimes a considerable advantage to measure these low-resistive reactances as admittances rather than as impedances, as reasonably large readings free from harmonic trouble can be obtained.

Most commercial oscilloscopes are arranged with time constants in the amplifiers, etc., enabling them to amplify down to very low frequencies.

In consequence they do not like switching operations. The spot is apt to be thrown off the scale, and it takes some time for it to regain its new position.

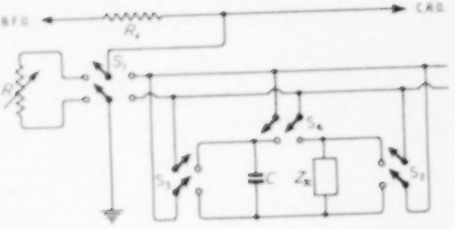


Fig. 6. *Practical arrangement of the apparatus; R and C are resistance and capacitance boxes respectively and Z_x is the unknown impedance.*

This can be corrected by reducing the valve coupling capacitors in the oscilloscopes used to much smaller values, not sufficiently small, however, to interfere with the amplification at the frequencies being used.

In the average laboratory there is a lot of mush liable to be picked up when large amplification is used, particularly when capacitors are being measured. This mush is mostly of fairly low frequency and tends to give blurred reading edges or points.

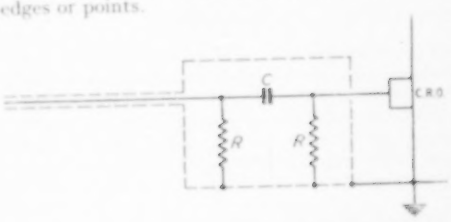


Fig. 7. *This diagram shows a method of reducing mush; it consists of the insertion of a screened filter in the connection to the oscilloscope. For cut-off below 1,000 c/s, suitable values are $R = 100$ kΩ and $C = 0.002$ μF.*

This is best countered by inserting a small resistive high-pass filter, cutting off below, say, 1,000 c/s fitted in a small earthed shielding box on to the c.r.o. amplifier terminal, as shown in Fig 7.

Frequency Stability

For particular work where great accuracy of frequency measurement is necessary, a frequency checking method based on multiples of a standard 1,000 c/s fork can be used, the chief point being to assure that there is no frequency drift of the b.f.o. during a series of measurements.

Components

Switches

For switching arrangements four telephone key-type switches were used in the original apparatus and fitted on a panel with other necessary terminals for connecting the b.f.o., c.r.o., unknown, resistance box and capacitance box. Some watch has to be kept on these telephone key switches to see that contacts are good, but a dirty switch will at once show up during a measurement.

One or two switching arrangements were made up with a better type of switch of the low-capacitance type. Ordinary porcelain-based, double-pole, double- and single-throw switches fitted to a breadboard are quite satisfactory, but possibly not so neat in appearance.

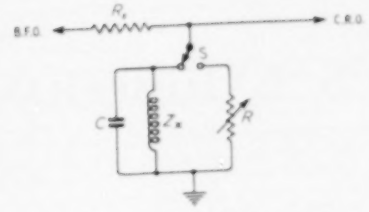


Fig. 8. *Connection for admittance determination.*

Resistance and Capacitance Boxes

Any well-known resistance box of the non-inductive type will do, but probably it would be advisable to check whether the inductance is really negligible, and this can be done by comparing its action against resistances of the rod type over a wide range of frequency.

The mica capacitors used were made up in a decade form. They were all tested to see if they were up to standard, but their exact value was not noted as this is determined when the measurements are being made.

Of course such a box is far cheaper than a proper decade box with its accurate capacitors and can usually be made up with stock capacitors from the laboratory. Snap switches of a miniature lighting type enable each capacitor to be thrown in at will.

For general use three decades were used, viz., 0.5, 0.2, 0.2, 0.1 μF, 0.05, 0.02, 0.02, 0.01 μF and 0.005, 0.002, 0.002, 0.001 μF.

A good mica capacitor has extremely small loss, but if one is suspected for loss it can be compared against one or two others of about the same value using the b.f.o. as a source of variable a.c. and resonating them with a high-Q coil.

Applications

The original apparatus was mainly used for determining the behaviour of ferro-magnetic cores—particularly when the latter exhibit magnetostriction effects. In these cases it is sometimes desired to take impedance measurements at much larger flux densities than would be given by the swamping resistance constant-current method, as the latter would become very uneconomical. It was found that satisfactory results could easily be obtained by replacing the swamping resistance by a thermal meter. Actually a large power amplifier was inserted after the b.f.o. and readings taken with powers up to 100 watts.

If the apparatus is maintained in an operating condition it will be found to be extremely useful for determining quickly, resistance values, capacitor values, resonance curves, network impedances, line impedances and for certain valve impedances which are of comparatively low value.

Admittance Measurement

The method obviously lends itself to the direct measurement of admittance, a little calculation being necessary to obtain mhos from ohms after each balance.

In the admittance measurement the added capacitor C should be placed in parallel with the unknown. The diagram for this is shown in Fig. 8 and the graph for the determination of the admittance vector is shown in Fig. 9 where the distance OA represents the admittance of the added capacitor.

The final vector OV measured in mhos, if arithmetically inverted, gives of course the impedance, the vector angle remaining the same value but negative.

It will be noted that the switching system of Fig. 6 permits the paralleling of the capacitor with the unknown by throwing S_2 and S_3 together ready for the balancing operation.

Fig. 9. *Diagram for admittance determination.*

The admittance measurement is very useful when the resistive component of the impedance is small (i.e., the Q value is high) because in this case when a series additional capacitor is used and the second balance obtained readings are rather small, amplification has to be large and harmonics tend to show up.

The admittance values, being balanced by a large resistance, do not suffer from these troubles.

Errors and Defects

In attempting to maintain constant current by a swamping resistance unless the ratio of the resistance to the unknown is infinite some error will usually be introduced when the unknown is reactive for the total current passing is then slightly larger than if the unknown were resistive.

Roughly, one can say that if the swamping resistance is ten times the unknown then there will be a possible 10 per cent error, and if the swamping resistance is 100 times the unknown, there will be a 1 per cent possible error. These lie well within the order of other errors.

Of course the error does not occur if the unknown is only resistive.

The usual practice is to vary the swamping resistance according to the job being done, taking a reasonable balance between the error likely to be introduced by too low a resistance and the fact that it is not quite so nice if the amplification has to be too large.

Impedances below 2 or 3 ohms are troublesome to measure owing to the various lead impedances, and impedances over 500 ohms will require swamping resistances of sufficiently large value to give capacitance errors at the higher frequencies.

The usual practice with the c.r.o. is to operate it with a time base working—one which does not show a distinct waveform being preferable unless it is desired to watch the waveform. This will allow a top and bottom edge to be set between horizontal lines marked on the tube—if a spot only were used there would be a tendency to burn the tube.

PHYSICAL SOCIETY'S EXHIBITION

THE 34th annual exhibition of scientific instruments and apparatus organized by the Physical Society was held at Imperial College, London, from 31st March to 5th April. The attendance was at least as large as ever, but complaints of overcrowding last year appeared to have been heeded, for there was a marked improvement, obtained by extending the exhibition both in space and time. Although there was again no official division into Trade and Research sections, the group of stands occupied by the considerable number of establishments now included in the Department of Scientific and Industrial Research and the Ministry of Supply comprised in effect a distinct research section. Except for a few of the larger firms, the commercial exhibitors confined their items mainly to production or prototype models.

Materials

A material of increasing importance in the radio and electronic industry is the element germanium, of which a number of applications were shown. As a result of co-operation between the G.E.C. Research Laboratories and Johnson, Matthey, processes have been established for extracting it from flue dusts. Specimens of the dust, of the oxide and of the metal, were shown on the G.E.C. stand. Another element now being produced in this country is tantalum, which was featured by Murex, along with tungsten and molybdenum.

Progress in permanent-magnet alloys continues; an outstanding development, which was shown by the Permanent Magnet Association, is Alcomax having orientated columnar crystal growth, with BH_{max} as high as 8×10^6 gauss-oersteds. For magnets in which anisotropic materials such as this are unsuitable, there is Hynico II isotropic alloy; BH_{max} 1.6×10^6. Some examples were shown of the remarkable reduction in size, weight and cost of magnets for meters, loudspeakers, television focusing, etc.

Another magnetic material with which progress has been made since last year is the non-conductive ferrite group. Mullard demonstrated Ferroxcube IV and V; the advantages of IV over III are the higher a.c. resistivity and the lower permittivity, enabling it to be used advantageously at frequencies as high as 100 Mc/s. Ferroxcube V has been developed for its higher saturation magnetization (4500–5000 gauss). The absence of eddy-current loss renders these materials particularly valuable for low-loss high-frequency magnetic cores, but there are many other applications. For example, the Telecommunications Research Establishment demonstrated the use of their rapid loss of magnetic properties at the Curie point for thermostatic control. Caslam, the core material with a laminated structure shown last year by Plessey, has been further developed, mainly in the direction of improving its characteristics for the higher frequencies.

Progress was also to be noted in the group of ceramic materials with extremely high permittivity. While for some purposes the variableness of characteristics with temperature and the appreciable loss angle render them inapplicable, these properties are no disqualification for by-pass capacitors, in which the criterion is the minimum κ over the working range of temperature. This was illustrated on the Mullard stand with reference to the new material K.3000, the name implying that the permittivity is greater than 3000 over the range 10°C to 70° C. The possibilities of this material for thermostatic control were demonstrated by T.R.E. alongside the Ferroxcube method just mentioned. The characteristics give a practically linear reactance/temperature relationship over a range of at least 100° C.

Plessey showed conductive ceramics made up as resistors for values to 0.1 MΩ. By varying the composition the temperature coefficient can be made positive, negative, or zero; and the properties do not alter appreciably up to 400° C.

Johnson, Matthey's stand was, as usual, devoted mainly to alloys and other special materials. High-accuracy low-loss waveguide tubing is now available, with silver lining if required. This firm can also do circuit printing in silver paint fired on to glass or ceramic panels. Examples were also shown of silvered-mica plates for the manufacture of high-quality stable capacitors. An interesting feature is a 'grid' plate designed to enable the capacitance to be adjusted precisely to the desired value.

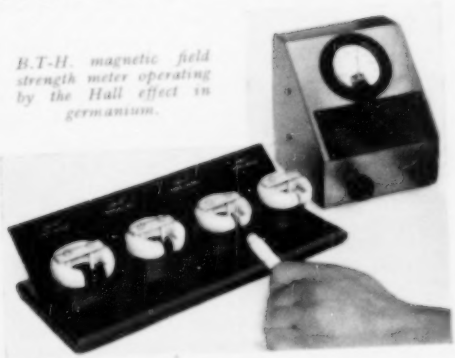
A remarkable demonstration of the piezo-electric properties of quartz was staged by Standard Telephones, in which a quartz sphere about the size of a golf ball was made to run continually up and down a pair of horizontal rails without visible motive power. The remarkable feature was that in doing so the ball did not rotate!

Components

The Standard Telephones exhibits also included sealed capacitors, illustrating successful manufacturing techniques, and demonstrations of thermistors. Among the increasing applications of thermistors is their use to protect the heaters of c.r. tubes in a.c./d.c. television receivers from switching-on surges. Among the components shown by Plessey were additions to their Breeze range of cable connectors and to their microwave accessories.

An ever-present need is a selection of instrument switches having good characteristics at a reasonable price, and W. G. Pye & Co. seem to have supplied it with their new A.218 series. These switches are available up to poles × ways = 12 per unit; the brush-to-contact resistance is given as 0.001Ω for beryllium-copper and 0.0002Ω for copper, and the thermal potentials less than 1μV. The former have been tested up to 100,000 operations without deterioration.

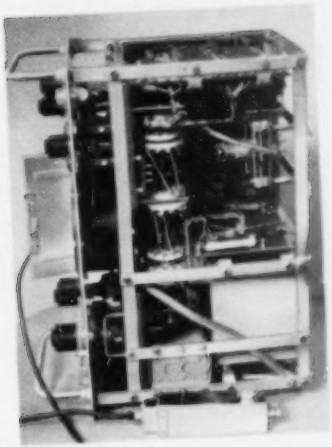
To avoid wearing and displacement of elements in the usual type of sine/cosine potentiometers, Elliott Bros. have introduced a new design in which simple replaceable elements are used and the law is obtained mechanically by a hypocycloid gear.



B.T-H. magnetic field strength meter operating by the Hall effect in germanium.

Meters

Although there was an excellent display of straightforward types of meters, there seems to be little scope for technical novelty in this field. Worth mentioning because of the scarcity of voltmeters suitable for present-day television c.r. tubes is the Everett Edgcumbe three-range portable electrostatic instrument reading up to 10 kV. The upper ranges are obtained by high-resistance multipliers, and the maximum current drain is about 10μA.



Interior of the AVO testmeter, type W tropical, showing the probe.

Magnetic measurement is another sphere in which availability of instruments has lagged behind requirements; and because of the very wide use now made of magnets the magnetic field strength meter shown by B.T-H. is particularly interesting. It employs the Hall effect in a minute piece of germanium mounted in a probe that can be used to explore quite small gaps. The probe is connected to a portable microammeter which is direct reading up to 25 kilogauss, in three ranges. This use of the Hall effect in germanium was also demonstrated by the G.E.C. Research Laboratories. Instruments for measurements of magnetic flux and permeability were shown by Metrovic.

A signal output power meter by Marconi Instruments was notable for the exceptionally wide power range—20μW to 10W. It includes also some interesting new techniques in the methods of covering the usual 2.5–20,000Ω impedance range over a frequency range of 500 : 1.

New types of valve voltmeter were not quite so numerous as in recent years; but there was a millivoltmeter by Airmec, using an amplifier with negative feedback to give ranges 0–10–100–1000 mV from 30 c/s to 5 Mc/s. Another was the AVO precision valve voltmeter, combining a wide range of a.c. and d.c. measurement with BS 1 accuracy. The basis is a double-triode amplifier, with active and compensating diodes for a.c. An example of the same class of instrument was shown by Electronic Instruments. The AVO type W wide-range electronic test meter was displayed in tropical form.

Amplifiers

Closely connected with the meter category is the AVO Television Signal-Strength Adapter, which aroused considerable interest owing to the increasing rate of television receiver installation and the great value of having some idea of the signal strength available on site. This instrument consists of an amplifier made up in the well-known AVO format and giving a gain of 20,000 over one of the television channels. The aerial is plugged in, and the signal strength is read in microvolts on an electronic testmeter or other valve voltmeter.

Other types of amplifier on view exemplified progress in frequency range at both ends of the scale, and high gain with stability, especially at zero frequency. The zero and very low frequency types have been developed for physiological applications, strain-gauge recording, and other special uses, and can be classified into those using direct couplings with stabilization, and those in which the signal is modulated in order to raise the frequency. Examples of the former class were shown by Pye and Southern Instruments, and of the latter by Tinsley and Sunvic. Extension into the high frequencies is chiefly in the interests of oscillography; high-gain amplifiers covering 0–10 Mc/s were prominent among the Nagard exhibits, both separate and incorporated into oscilloscopes. At the other extreme was an amplifier shown by T.R.E., using a twin-T RC network, with a bandwidth of 1 c/s at 1,000 c/s, designed to select a signal from a noisy background. The same type of network was used by Tinsley in a bridge amplifier tunable over the exceptionally wide range of 16 c/s to 160 kc/s.

A simple type of self-rectifying amplifier is the essence of a compact electronic relay by Labgear, controlling up to 1 kW with 20μA input.

An amplifier for demonstrating a.f. technique in schools, etc., was among the 'custom-built' units shown by A. E. Cawkell. Magnetic amplifiers were to be seen in various applications. In a demonstration by Electro Methods, a multi-stage magnetic amplifier was coupled to an integrating motor, the effective starting power being $10^{-2}\mu$W.

Oscillators and Signal Generators

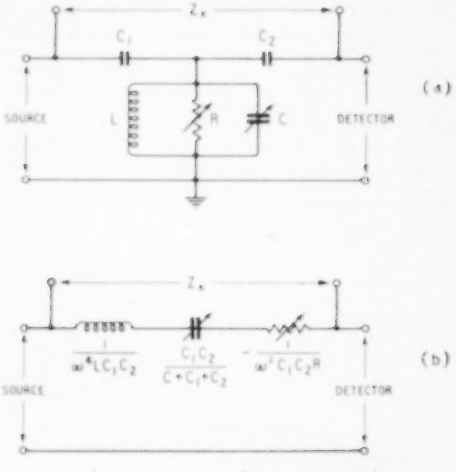
A number of firms showed new or improved a.f. oscillators, usually RC types, covering 20–20,000 c/s in three decades (Dawe, Pye, and Muirhead), but occasionally with a wider range (15–50,000 c/s, Advance Components; and 10–100,000 c/s, Cinema-Television). The trend is in favour of resistance-variation and thermistor amplitude-control, and improvements are chiefly in the direction of purer waveform and more constant amplitude. A v.f. oscillator (7 kc/s to 8 Mc/s) by Wayne Kerr covers the band in 6 ranges of 'straight' LC tuning, with total harmonic distortion less than 0.2% and amplitude variation not exceeding 0.1 db.

In the r.f. field, there were examples of frequency modulation and pulse modulation. The f.m. signal generator E.7572 by Mullard is intended for servicing receivers in the 80–104 Mc/s band; both sinusoidal and saw-tooth modulation are provided. In a new signal generator (TF.995) by Marconi Instruments, both f.m. and a.m. are available over a carrier-frequency range of 13.5–216 Mc/s; a crystal calibrator is built in. The same firm was showing a 8–14 cm oscillator employing a reflex klystron with non-contact piston tuning. A coaxial-line velocity-modulated oscillator of the single-transit type shown by Standard Telephones was arranged for f.m. with a high degree of linearity (third harmonic, — 65 db, for 1.75 Mc/s deviation) for microwave links. Square-wave and pulse technique was exemplified in a 600–1,215 Mc/s signal generator on the T.R.E. stand.

The great value for testing purposes of a source of square waves and pulses with a very short time of rise was demonstrated by Cinema-Television with their generator in which the time of rise is of the order of 0.015μsec. Pulse widths of 0.05–0.3μsec are available. Incidentally, a very special oscilloscope was needed to show the sharpness of waveform. Circuits for the generation of pulses as brief as 0.01μsec were shown by G.E.C.

Bridges and Standards

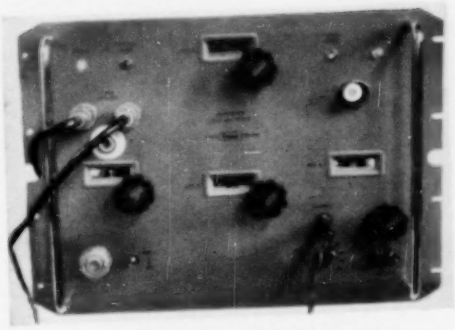
An addition to the Wayne Kerr series of bridges was an experimental a.f. model in which the interesting feature is the replacement of variable C and R standards with fixed standards connected to decade variable-ratio transformers. A transformer error of only 0.001% up to 1 kc/s is claimed for a unit covering five decades. Besides reducing the cost of highly accurate standards, this system reduces residual errors by enabling the impedance of the bridge to be extremely low. The present trend towards inductively-coupled ratio arms or other devices to bring both source and detector to earth potential so



Circuit of 50–100 Mc/s T bridge (a) and its equivalent network (b) shown by S.R.D.E.

that components can be measured *in situ* regardless of the impedance from their terminals to earth was seen in two bridges by Cinema-Television; one for C and R and the other for L and M, both covering very wide ranges, with convenience in use and freedom from stray effects even when measuring small fractions of 1 pF or of 1μH.

The accompanying circuit diagram shows, at (a), the form of a 50–100-Mc/s T bridge network demonstrated by S.R.D.E. Its electrical equivalent is as at (b), from which it can be seen that the standards provide negative resistance and both positive and negative reactance, enabling an unknown impedance to be balanced out and its resistance and reactance determined from the relationships stated on the diagram.



Plessey wavemeter covering 15–10,000 Mc/s.

Among the various standards may be mentioned: push-button v.h.f. attenuators by Standard Telephones covering 0–9 db in 1-db steps or 0–90 db in 10-db steps up to 100 Mc/s; resistance standards by Tinsley with an accuracy of 1 in 10^5; an extension of the Muirhead universal series to include highly-stable units of 2 MΩ each; small standard Weston cells by Muirhead and Doran (the latter operable in any position); and quartz frequency standards as low as 400 c/s by Salford Electrical Instruments. Measurement of exceptionally high frequencies is provided for with an accuracy of 1 in 10^5 in the Plessey Test Set 272 covering 15–10,000 Mc/s, by reference to a calibrated butterfly-circuit oscillator of 400–800 Mc/s, in conjunction with other oscillators and a 100-kc/s crystal. A G.E.C. demonstration showed how still higher frequencies, in the 20–30 kMc/s band, can be measured by reference to molecular resonance of ammonia, contained in a coiled waveguide.

Valves and Cathode-Ray Tubes

Important new types of valves were conspicuously absent, unless one includes transistors (germanium-crystal triodes). These have been considerably developed, and the production difficulties and fragility associated with critically-spaced 'cat-whiskers' have been largely overcome. In the design shown by G.E.C. they are replaced by two plates separated by a known and accurately controlled spacing. Applications on view included a miniature 3-stage amplifier with a gain of 66 db.

The E.M.I. Multiplier Photo-tube, which is an 11-stage electron multiplier with a photo-electric cathode, having an overall multiplication of about 10^7, was shown in two improved forms. It is used in television film-scanning equipment and still more widely in nuclear research as a scintillation detector.

The cathode-ray tubes shown by 20th Century Electronics were designed as precision instruments. They have flat screens and the electrodes and deflector plates are accurately aligned in a rigid mounting. The double-beam type has common X plates but separate Y plates and guns, and is therefore free from inter-modulation.

Oscilloscopes

As mentioned in connection with amplifiers, the trend is towards wider ranges of frequency, and it is now normal for instruments to include z.f. amplification. An outstanding example was shown by Mullard, with identical X and Y amplifiers effective from 0–20 Mc/s. The Nagard instrument can be made up to a variety of specifications, including the amplifiers already referred to, and is designed for accurate measurement of time, frequency, and voltage. The power unit is separate. Another oscilloscope with z.f. amplifiers was that shown by Industrial Electronics, in which the time-base frequency can be made as low as a few cycles per minute. T.R.E. exhibited a large console type of laboratory oscilloscope with 12-inch tube, designed to give the utmost accuracy of measurement. Equipment on the Avimo stand was devoted to oscillography, as distinct from oscilloscopy, and included high-speed recording cameras. In a specialized type of instrument shown by the Armament Research Establishment, for the accurate timing of events, the display took the form of a crystal-controlled spiral, giving a 50-μsec base on which events at intervals of from 0.2μsec can be recorded with an accuracy of 0.02%.

Industrial Electronics audio-frequency response-curve tracer.

Special Apparatus

Some of the instruments in this category could be regarded as oscilloscopes plus; for example, the Industrial Electronics portable a.f. curve tracer, which consists of a b.f. oscillator with automatic frequency sweep, in conjunction with a c.r. oscilloscope. The Y deflection is obtained from the output of the apparatus under test, and the X deflection is provided by a RC discriminating circuit giving a voltage proportional to the logarithm of the oscillator frequency. The Standard Telephones cable-testing equipment employs radar technique with a c.r. tube display, to detect any non-

uniformity of impedance such as would be caused by a fault, and to indicate its distance from the point of test. Other tests, such as loss measurement and velocity ratio, can be easily performed with the same equipment.

If a prize were to be awarded for the instrument which would keep visiting radio engineers instructively entertained for the longest period by manipulating the knobs, it would almost certainly have gone last year to the Cinema-Television valve tester (seen now in production

Cintel pulse generator with a pulse rise-time of 0.015μsec.

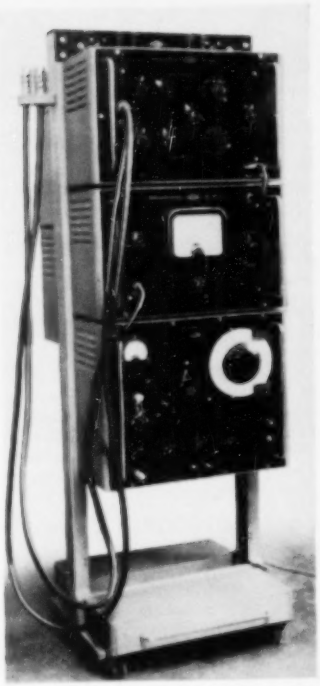
form). This year it would no doubt have been earned by another c.r. instrument—the T.M.C. electronic analogue computor for directional aerial arrays. This is provided with current, phase, and spatial angle knobs for each of three aerial dipoles; and by turning these the corresponding radiation pattern of the array can be seen on the screen. As an alternative to laborious trial-and-error computations, or field-strength measurements, there is very much to be said for this scheme, by which the result of any combination of parameters can be seen in a few seconds.

In view of the importance of the Nyquist criterion in modern amplifier design, the phase-measuring equipment made by Airmec for the G.P.O. Research Department is of great interest. Its frequency range is 50 kc/s to 20 Mc/s, and accuracy of measurement ± 3%. Contact with the two points between which the phase angle is to be measured is made by two probes having an input capacitance of 6 pF; and the range of input level is 66–27 db below 1 V.

In addition to those already mentioned, new Marconi Instruments items on show included a 8–11-cm oscillator, a spectrum analyser for testing magnetrons in the same band, a 3-cm waveguide test bench, a noise-factor meter incorporating a calibrated noise diode, a receiver tester improved by the addition of a 1-db step attenuator and a mechanical frequency-increment control, and an a.f. change-of-level recorder. An instrument of the last-named type was also shown by Dawe; and a spectrum analyser for the 3-cm waveband by Elliott Bros. Comprehensive 3-cm and 10-cm waveguide test equipment was among the B.T.-H. display.

Measurement of noise factor at 10,000 Mc/s (of travelling-wave amplifier tubes) was demonstrated by Mullard with a waveguide set-up in which a signal from a klystron could be passed either direct or via the amplifier. Another Mullard demonstration showed measurement of valve input damping in the range 10–150 Mc/s. It was based on the voltage developed across a tuned input circuit. A direct-reading f.m. deviation meter was shown by the Signals Research & Development Establishment, for measuring deviations up to 500 kc/s at frequencies up to 120 kc/s, on carriers of 20–100 Mc/s, to an accuracy better than 2%.

In acoustical measurements, one of the difficulties has been that of completely suppressing reflections at the lowest frequencies. The solution adopted at the National Physical Laboratory was illustrated by a model of a duct, reminiscent of a large-scale waveguide, with one end containing the source of sound and the other terminated by absorbing wedges. The microphone, located about midway, is subjected to a plane progressive wave, disturbing effects being reduced to the order of 1% in the range 25–450 c/s.

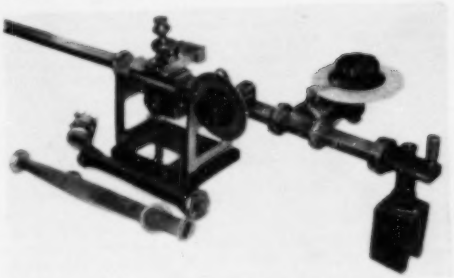


Airmec phase-measuring equipment covering 50 kc/s to 20 Mc/s.

Power Supplies

Many exhibits illustrated the interest in stabilization of power supplies to meet increasingly exacting requirements. For smoothing out a.c. mains voltage variation, the improved Zenith automatic voltage regulator provides for up to 20 kVA single-phase. It has a motor-

driven regulator controlled by a non-linear a.c. resistance bridge with two tungsten-lamp arms. The Tinsley a.c. stabilizer, to Dr. Patchett's design, deals more precisely with smaller amounts of power (0.5 kVA), giving a short-



Marconi Instruments standing-wave detector.

term stability of 1 in 5,000, and is compensated for temperature variations. An example of the the well-known negative-feedback type of voltage stabilization applied to rectified and smoothed a.c. was shown by A. E. Cawkell, with heater stabilization of the valves in order to give a much closer control than is possible without. Current stabilization, other than by simple barretter lamps, has not had so much attention, but a method demonstrated by the British Scientific Instrument Research Association made use of a saturated transductor to stabilize heater current at any pre-set value between 0.2 and 0.6A r.m.s.

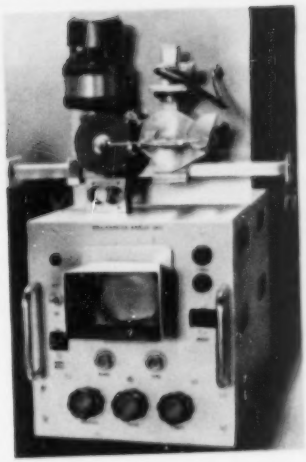
The Eliminac l.t. power unit by Labgear is not stabilized, but provides 0–15 V d.c. with extremely small ripple (0.1% at 5 A and 0.01% at 2 A), in addition to 0–20 V 10 A a.c.

Research

A number of exhibits of the research establishments have already been mentioned, and many others fall outside the scope of this journal. An interesting joint display by T.R.E. and the Meteorological Office explained the working of the most recent form of balloon-borne meteorology—the radar sonde. By its means a single ground station automatically keeps a continuous record of the height of the balloon and (from its motion) wind speed and direction, as well as receiving the atmospheric data transmitted by it—pressure, temperature and humidity. The ground station sends pulses on a wavelength of 2 metres, which are returned by a transponder in the balloon on 10 cm. The distance is determined in the usual way by the transit time, and the bearing and elevation from an auto-follow aerial system; the information is fed into a computor. The data registered on the balloon-borne instruments are conveyed by pulses following the range pulse.

Peculiarities of radio propagation over a land-and-sea path were demonstrated by Marconi's Wireless Telegraph Co. with a small-scale model, using a fixed directional 3-cm sender and a receiver mounted on a small trolley. Sea was simulated by a metal sheet and land by metal covered with paxolin.

A resistor network for solving partial differential equations, such as Laplace's and Poisson's, to high accuracy (1 part in 10^3 to 10^4) was shown by the A.E.I. Research Laboratory applied to the calculation of the electric-field pattern in an electron lens.



Elliot X-band spectrum analyser.

A demonstration by B.T.-H. showed a new system of pulsing high-power 3-cm magnetrons without the use of any valves or discharge devices. The circuit consisted of a chain of saturated reactors (named Pulsactors) utilizing the extremely sharp magnetization knee of core materials such as H.C.R. metal to provide the pulse-switching action. The system has the advantages of long life and stability.

CORRESPONDENCE

Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Electron Transit Time

SIR,—In your February issue there is an article by Chatterjee and Sreekantan on the effects of electron transit time on negative-grid oscillators. In that article the authors use certain formulae of mine but they do not take sufficient account of the assumptions made in deriving the formulae. There are several aspects of their paper which are open to question but I would particularly refer to their use of the equation*

$$\eta_1 - \eta_2 = \frac{\sqrt{2}}{\pi}\frac{I_g}{E_a}\omega^2\tau^2$$

which is the same as equation (5) in their paper. This formula gives the difference between the low-frequency efficiency, η_1, and the efficiency, η_2, at a frequency corresponding to a transit angle of $\omega\tau$. In deriving the formula it was assumed that the *only* effect of the electron-transit time was to introduce a phase delay in the anode current pulse, so that the maximum current did not occur at minimum anode voltage. This assumption was made originally in an attempt to establish a connection between the efficiency and the *onset* of transit-time effects. In view of the simplifying assumptions made in deriving the above formula, its application to much higher frequencies is unjustifiable. When the transit time is an appreciable fraction of the alternating period, the shape of the anode-current pulse will differ considerably from its shape at low frequencies. Again, the kinetic energy of the electrons at the anode will not correspond to the potential of the anode at the instant of arrival. In view of these and other assumptions, it is not surprising that Chatterjee and Sreekantan found very little correlation between the observed and calculated values of their λ_g.

Cambuslang,
Glasgow. M. R. GAVIN

* *Wireless Engineer*, June 1939, Vol. 16, p. 287.

Background Noise in Photomultipliers

SIR,—It is a fairly common observation that incident radiation causes the background noise to increase, beyond the level due to 'dark current' alone. This is expressed by the noise equation (1) which has appeared elsewhere[1]. It seems worthwhile to present this equation in a more explicit form, since a number of important conclusions are to be derived from it.

The mean square value of shot-noise current, in a bandwidth range B cycles per sec, is

$$\overline{<i>^2} = 2e\,(\bar{i} + i_s)\,B \qquad \ldots \quad (1)$$

where i, i_s are the respective values of 'dark current' and emission current from the photocathode.

Suppose that the signal current (i.e., i_s) is to be s times the r.m.s. amplitude of the noise current, then

$$i_s^2/s^2 = 2e\,(\bar{i} + i_s)\,B \qquad \ldots \quad (2)$$

so that

$$i_s^2 - 2e s^2 B\, i_s - 2e s^2 B\, \bar{i} = 0 \qquad \ldots \quad (3)$$

and therefore

$$i_s \text{ must equal } es^2B\left[1 + \sqrt{1 + \frac{2\bar{i}}{es^2B}}\right] \qquad \ldots \quad (4)$$

Consequently for a given signal-to-noise ratio the required value of i_s is not much affected by $\bar{i}$, provided that $\bar{i}$ falls below, say, $\left(\frac{es^2B}{2}\right)$.

For wideband amplifiers $\bar{i}$ need not be so small as for a narrow band. Further, it should be noted that effects of refrigeration cannot be assessed without a knowledge of the values of s and B which are needed for any particular application.

New Barnet, Herts. S. RODDA

[1] Engstrom, R. W., *J. opt. Soc. Amer.*, June 1947. (Equ. 3).

Change of Mutual Conductance with Frequency

SIR,—In the March 1950 issue there is a letter by Eisenstein reporting on the results of a study of the decay of anode current passed by a pentode when a square voltage pulse is applied to the grid. The results are explained by the development of a homogeneous interface compound sandwiched between the coating and the base metal of the cathode. Eisenstein states that this, rather than the inhomogeneous poor contact hypothesis offered by Raudorf, is the correct explanation of the change of g_m observed by Raudorf[1].

As a matter of fact the frequency dependence of g_m was first blamed on the development of an interface compound when, some ten years ago, the change of mutual conductance with frequency in the course of operation caused serious trouble in communication receivers of the R.P.Z. (Reichspost Zentralamt). It turned out, however, that this was not justified. The geometrical structure of the base metal proved to have a decisive effect on the development of the cathode impedance, in comparison with which the influence of an interface compound was of minor importance. The improved behaviour of flat cathodes was confirmed by measurements on a range of valves of German and foreign make. It would be interesting to hear whether Eisenstein investigated the influence of the curvature of the core surface on the development of the cathode impedance before writing his letter.

Department of Physics,
University of Birmingham. W. RAUDORF

[1] W. Raudorf, *Wireless Engineer*, October 1949

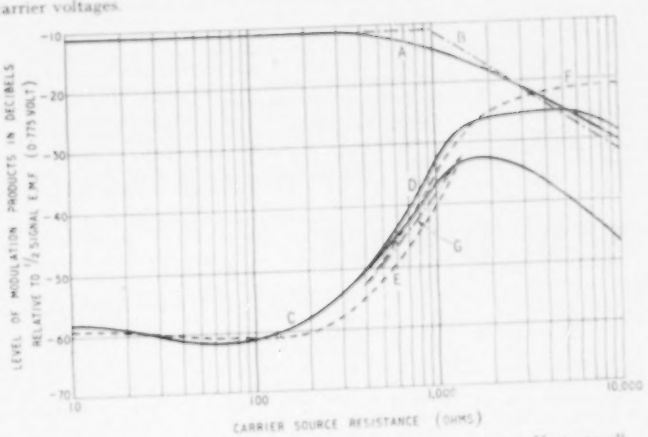
Non-Linear Distortion in a Cowan Modulator

SIR,—The main non-linear distortion product $f_s + 3f_c$ in balanced rectifier modulators was calculated in previous letters[1, 2]. Although the theoretical distortion agrees with published experimental results[3] for the ring modulator, there is an apparent numerical discrepancy between the predicted distortion and results obtained by Tucker and Jeynes[4] for the Cowan modulator.

The latter experiments are difficult to interpret because the practical conditions do not permit a simple approximate calculation. Using the notation of reference (2), it is apparent that the approximate formula (18) deduced there from (16) is only correct when both cV_s/V_c and bV_s/V_c are small compared to 1. Now, in the experiment, bV_s/V_c has the constant value 0.43 and cV_s/V_c is equal to 1 for a c.s.r. (carrier source resistance) of 100 ohms, so that a second overload occurs for smaller resistances. Thus, the conditions for the approximate formula (18) are not met and the comparison with a more rigorous expression derived from (16) would require lengthy calculations using elliptic integrals, because of the strong interaction between the two overload effects.

It seemed thus necessary to reproduce the experiments choosing more convenient practical conditions.

It appeared also preferable to adopt the carrier e.m.f., and not the positive peak p.d., as reference variable. In a Cowan modulator without a complementary rectifier in opposite connection the positive and negative peaks of the carrier p.d. are different and difficult to measure directly; also, the carrier p.d. contains a d.c. component which (unless adequate precautions are taken) is shunted by the d.c. resistance of the carrier source and this produces a complicated readjustment of the carrier voltages.



Bridge modulator in a 600-Ω circuit; carrier e.m.f. = 0.775 V + 10 db. Curve A, output level of $f_s - f_c$; curve B, asymptotes crossing at the theoretical overload point (950-Ω); curve C, output level of $f_s - 3f_c$; curve D, distortion margin calculated from C − A + 11 db; curve E, theoretical value for C calculated by Equ. (2) holding for low c.s.r.; curve F, theoretical value for C calculated by Equ. (3) holding for high c.s.r.; curve G, common asymptote of E and F.

The basic equations of Ref. (2) were thus first rewritten in terms of the carrier e.m.f. E_c, which is directly measurable, and this produced a simplification in the formulae which no longer depend essentially on the rectifier ratio. It was, therefore, permissible to assume ideal rectifiers ($g_0 = 0$, $g_i = \infty$) and the comparison with experiment involves no knowledge of numerical data on the rectifiers.

In terms of the instantaneous carrier e.m.f. e_c, equation (16) of ref. (2) becomes, for an ideal modulator,

$$v' = \frac{1}{2(1+x)}\,[F(e_c, E_s) + F(e_c, xV_s)] \quad \ldots \quad \ldots \quad (1)$$

where $x = 2r/R$ is the ratio of the c.s.r. to the circuit source and load in parallel. By choosing for E_s in the experiment a constant value somewhat larger than V_s, the overload due to the first term of (1) will be avoided but, if the c.s.r. is gradually increased, an overload point due to the second term will occur for $xV_s = E_c$. Before this overload, the distortion ratio is given by

$$V_{12}/V_{11} = \frac{1}{24}\,(V_s/E_c)^2\,(x^2 - x + 1) \quad \ldots \quad \ldots \quad (2)$$

and is minimum for $x = 1/2$. This is merely equation (18) of ref. (2) in the new notation. Near the overload point the rigorous expression involving elliptic integrals must be used for the second term in (1) but the contribution of the first term is negligible. The effect of the second term can be obtained graphically from the curves of reference (1). Denoting by $D(k)$ the distortion margin read on these curves (interval between curves marked V_{11} and V_{12}) for a signal to carrier ratio k, the distortion margin in our case will be

$$D\,(xV_s/E_c) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

The results shown in the figure refer to a modulator composed of four KH1 copper-oxide rectifiers working between 600 ohms source and load. Both the signal and the carrier were in the voice-frequency range and varied to give 800 c/s for the modulation product being detected. The signal level ($\frac{1}{2}$ e.m.f.) was kept to 0 db relative to 1 mW in 600 ohms and the carrier e.m.f. was 10-db higher. First, the main sideband level (curve A) was measured. The theoretical overload point corresponds to $20 \log x = 10$ db; i.e., to a c.s.r. of $300 \times 3.15 = 950$ ohms. This is marked B on the figure and the theoretical asymptote after overload has a negative slope of 20 db per decade of c.s.r.

The measured distortion V_{12} is curve C and the resulting distortion margin (except for the additive constant − 11 db) is curve D which coincides with C before overload. The margin calculated by equation (2) and using the known level − 11 db of V_{11} gives curve E, the theoretical value at zero c.s.r. being $-27.6 - 11 = -20 = 58.6$ db and curve F is the margin calculated by (3) and plotted downwards from the − 11-db line. Curve G is the common asymptote

$$V_{12}/V_{11} = (xV_s/E_c)^2/24$$

of both theoretical expressions and is a straight line of 40-db slope per decade of c.s.r., the intercept at the overload point being $-27.6 - 11 = -38.6$ db.

The agreement between theory and experiment is satisfactory even for relatively high values of the c.s.r. As this corresponds to quite small positive peak carrier p.d. definitely in the non-linear part of rectifier characteristics, the experiment evidently shows that the exact rectifier law is not essential and that the distortion entirely depends on the effect of the signal voltage shifting relatively to each other, the intervals of steep resistance change of the two pairs of rectifiers.

A similar statement holds for another kind of phenomenon. The presence of a spurious carrier f'_c modifies the simply periodic character of the rectangular switching function of frequency f_s. The difference between the switching functions with and without the spurious carrier is a wave composed of pulses of periodicity f_s modulated in width by f'_c. The harmonic analysis of such a wave gives an infinite number of components $mf_s \pm f'c$, with m even or zero, and all having the same amplitude. An elementary calculation shows that, if the spurious carrier is A decibels below the main carrier, an infinite number of spurious modulation products $mf_s \pm f'c \pm f_s$ (m even or zero) will be present in the output at $A + 6$ db below the main sideband level. This was checked experimentally with $A = 30$ db using a Cowan modulator with a fifth opposing rectifier and, up to $m = 12$, the level drop of the spurious products was only 5 db.

Brussels, Belgium. V. Belevitch.

REFERENCES

1. V. Belevitch, *Wireless Engineer*, May 1949, Vol. 26, p. 177.
2. V. Belevitch, *Wireless Engineer*, April 1950, Vol. 27, p. 130.
3. R. S. Caruthers, *Bell Syst. tech. J.*, April 1939, p. 315; see fig. 3.
4. D. G. Tucker, E. Jeynes, *Wireless Engineer*, Feb. 1950, Vol. 27, p. 66.

Gain of Aerial Systems

SIR,—Your contributor Mr. D. A. Bell suggests in Appendix II of his paper (*Wireless Engineer*, September 1949), and again in a letter (January 1950), that it is "theoretically possible for a limited spectral distribution of energy to produce a train of repeated pulses in which each pulse has any desired degree of narrowness."

This statement would be correct if the Fourier transform of an aperture distribution gave the polar diagram as a function of θ, the angle with the normal to the aperture. In fact the variable in the Fourier transform is $\sin\theta$, which is therefore the exact analogy of time in the circuit problem. Now only that part of the Fourier transform in which $|\sin\theta| \leqslant 1$ corresponds to the radiated polar diagram, so that obtaining an abnormally narrow diagram in this region corresponds to getting an abnormally sharp pulse in a given finite range of time. Outside this range of time the function will in general be very large indeed, as an examination of the examples given in our paper* show.

Thus the circuit analogue of an anomalously narrow beam aerial is a pulse, obtained from a limited spectrum of frequencies, which during a finite interval of time, has a sharp peak, but which has broad "humps" of very large amplitude outside the specified time interval.

Furthermore, if the aerial has a continuous aperture distribution, there will be one pulse only, but if the aperture distribution is composed of discrete sources spaced d apart, the polar diagram will be periodic in $\sin\theta$ with period λ/d, so that the circuit analogue is a train of pulses. If $\lambda/d > 2$ the period will extend beyond the $|\sin\theta| \leqslant 1$ region, so that in the circuit analogue sharp pulses and large "humps" will occur alternately; if $\lambda/d < 2$ the period will not extend beyond the $|\sin\theta| \leqslant 1$ region, and under these conditions anomalously high gain cannot be obtained.

Telecommunications Research Establishment. P. M. WOODWARD. J. D. LAWSON.

* *J. Instn elect. Engrs*, 1948, Vol. 95, Pt. III, p. 363.

NEW BOOKS

The Theory and Design of Electron Beams

By J. R. PIERCE. Pp. 197 + xiii. D. Van Nostrand Co., Inc., 250 Fourth Avenue, New York 3, U.S.A. Price $3.50.

Dr. Pierce, whose contributions to the design of microwave valves are well known, has written this short book to emphasize the aspects of electron optics which have to do with high-current low-voltage beams. These problems are of fundamental importance in valve design but most books on electron optics confine themselves to what might be termed geometric electron optics, in which the space-charge forces due to the electrons and ions in the beam are assumed to produce negligible effects. The theory thus developed applies well to such devices as electron microscopes and diffraction cameras, somewhat less well to modern cathode-ray tubes and hardly at all to the special types of valve using well-defined electron beams which are used at u.h.f.

The present book "represents an effort to collect together with reasonable orderliness the minimum amount of theoretical material necessary for a good understanding of electron flow and electron focusing in devices other than electron microscopes and image tubes." To this end rather more than half of the space is devoted to matter included in standard books on electron optics and only chapters 8, 9 and 10 deal with heavy-current flow. The basic theorems of electron optics are very clearly expounded, using the ordinary Newtonian forms of the equation of motion and the Lorentz force law. This treatment is much more suitable for beginners who have not specialized in geometrical optics than are the applications of least action, eiconals, etc., which are preferred particularly by German writers on the subject. Since in all practical heavy-current devices the geometrical aberrations are masked by space-charge effects it has not been necessary to deduce the elaborate theory of third-order errors. The treatment is made concrete by application to problems encountered in electron multipliers and beam-deflection tubes.

Turning now to the material dealing specifically with high currents, chapter 8 surveys the effects produced by thermal velocities. The main problem studied is the current density which is obtained when current from a cathode of given area and temperature is focused to a point or a line. In this case the beam is considered to have such a large cross-sectional area at all points, other than those in the immediate vicinity of the focus, that space charge is unimportant and the factor determining the current density is the spread of thermal velocities which plays a part analogous to chromatic aberration. The results, originally due to D. B. Langmuir, are here deduced by the use of Liouville's theorem, as was done in an important paper by the author. The maximum current density given by these results represents an absolute maximum which can never be exceeded. In many cases, however, space-charge forces along the length of the beam are far from negligible and the current density is limited by space-charge considerations; it may be long, therefore, before the thermal limit is approached. This case is the subject of chapter 9, which includes both electrically and magnetically-controlled beams. A short section on the influence of positive ions is included.

Chapter 10 treats the special types of electron gun in which the electron flow is rectilinear. These guns were introduced by the author and are now known as "Pierce" guns. The results of chapters 8 and 9 are then compared and it is shown how the angle of convergence, voltage and ratio of anode to cathode radius determine whether the thermal limit or the space-charge limit is operative.

The book is always clear and succinct, and the author has a very good knowledge of what is necessary and what can be neglected in this work. There are omissions, as is inevitable in a short pioneer monograph, and it is a pity that there should be no mention of the processes used for inserting a space-charge correction on trough plots or of the very general theory of beam focusing developed by Condon, Bunemann and Latter. Valve designers will welcome the book as a lucid exposition of problems whose solutions are scattered over an enormous literature and any research worker wishing to design an electron beam should consult it, if only to note Dr. Pierce's final remark that precious time may be lost by trying to do better than well enough. To Dr. Pierce belongs much of the credit for telling us how well we can ever do.

A. H. W. B.

Recent Advances in Radio Receivers

By L. A. MOXON, B.Sc.(Eng.), A.M.I.E.E. Pp. 183 with 92 illustrations. Cambridge University Press, 200 Euston Road, London, N.W.1. Price 18s.

The author of this book is a leading authority on the subject of noise in radio receivers and we must not be surprised that almost exactly one-half of this book

is devoted to this aspect of receiver design. The design of i.f. amplifiers is also covered in detail while there is a separate, and valuable, chapter on the measurement of noise factor.

The remainder of the book deals with recent trends in communication and commercial receiver design but is so synoptic in treatment that it will only preach to the converted and it is in the earlier chapters on noise that the main value of the book resides. Although the matter on noise is exhaustive, as far as it goes, one might reasonably have expected a fuller treatment of the physics of the subject, for instance no mention is made of the work of N. R. Campbell and V. J. Francis. Again, although circuit noise is treated, in extenso, there is less than a paragraph on partition noise; the expression for cathode and partition noise is given without supporting argument and the desirability of a high I_a/I_k ratio is deduced on the strength of this quoted formula alone. There is, in fact, a lack of emphasis throughout the book which must inevitably reduce its value to the advanced student, as distinct from the practising design engineer.

The chapter on i.f. amplification covers, in considerable detail, the design of multiple stagger-tuned amplifiers but transient response and time-delay are treated in a somewhat cursory manner (we have the surprising situation that this important aspect of design gets little more space than image rejection in short-wave superheterodynes).

Mathematical expositions have been avoided almost entirely, but the arguments are not necessarily easy to follow on that account. There is, for example, a marked absence of references to familiar concepts and expressions which should make a text flow freely; again it is not always clear whether a given expression should follow from the argument or whether it is being quoted from some other work.

Much of this lack of correlation can be attributed to the author's tendency to lift some of his material verbatim from his published articles; a very human frailty which rarely produces a really satisfactory result.

With the introduction of quantization methods of modulation, noise measurement assumes an added importance in the communications field and the chapter devoted to measurement can be unreservedly recommended to those who will be concerned with this subject.

The book is remarkably free from errors, as such, a careful check revealed only two, both fairly obvious and of minor importance.

As a whole, the book can be recommended because it brings under one cover much valuable information on receiver noise. One must, however, suggest that a more satisfying work could be produced, from the same pen, if the later miscellaneous chapters were excised in favour of an even more comprehensive statement on noise.

E. J.

Die Maxwellsche Theorie in veranderter Formulierung

By L. Kneissler. Pp. 51 and viii Springer-Verlag, Vienna.

This is a discussion of a suggested modification of Maxwell's theory. The author, who is a professor at Vienna, says that since the introduction of the Lorentz electron theory, Maxwell's theory has receded into the background. It was the difficulty of applying Maxwell's theory to magnetic fields in the presence of ferromagnetic materials that led the author to attempt a modification of the theory. The author states that his approach is that of a theoretical electrical engineer and not of a physicist. By eliminating magnetism and replacing it by the currents that produce it within the material, the author states that Maxwell's theory is brought into agreement with the electron theory in its macroscopic form. The book is divided into four chapters dealing with, I. fundamental equations, II. dielectric material; III magnetic material, and IV. the general electromagnetic field. There is a short appendix dealing with the system of units employed. The author published articles on the subject in the *Archiv fur Elektrotechnik* for 1940, 1941 and 1942, and the book is a development from these.

G. W. O. H.

The M.K.S. System of Electrical and Magnetic Units

(Decisions taken by the International Electrotechnical Commission)

B.S. 1637 : 1950. British Standards Institution, 24–28 Victoria Street, London, S.W.1. Price 2s.

It is stated in the Foreword to this 8-page memorandum that it does not express any opinions either for or against the system, but is issued with the object of putting on record in summarized form the decisions which have been arrived at internationally regarding the m.k.s. (Giorgi) system. At the Torquay meeting of the International Electrotechnical Commission in 1938 Professor Giorgi undertook to prepare a booklet, but owing to the war it did not materialize; hence the present memorandum. The question of rationalization is not discussed. A list is given of the principal units with definitions taken from Giorgi's memorandum, but modified where necessary to bring them into line with later decisions.

After defining the metre and kilogram the remark is made that " the metre and kilogram are the original units of the metric system; the centimetre has not a convenient size for everyday use, and nobody employs it in common life for measuring large distances or for deriving multiples and sub-multiples." This is not very convincing; one does not use the centimetre *nor the metre* for measuring large distances, and the gram is used for deriving multiples and sub-multiples, such as kilograms and milligrams. It has been suggested to us that the litre should have been mentioned, but although it is the most commonly used unit of volume in metric countries, it is not a unit of the m.k.s. system. It was also suggested that in giving the density of water as 1000, the temperature should have beeen specified, but it is not given as an accurate definition, but merely to indicate that the density is 1000 and not 1 in the m.k.s. system. The definition of the newton is very amusing. Instead of saying simply that it is the force that causes a mass of a kg to accelerate at 1 m/sec^2, we are told that it is " the gravitational force on (or weight of) a kg mass in a place (about 20,000 km from the centre of the earth) where the acceleration due to gravity would be 1 m/sec.^{2}" The unit of work or energy is " the joule which equals the product of a newton into a metre ", this seems a strange use of the word ' product '.

The definition of the ampere as " the value of a constant current which when maintained in two parallel conductors . . . " would be more precise if the current were maintained in *each* of two parallel conductors. On page 6 there is a reference to " two carrying conductors", we presume that the word ' current ' has been accidentally omitted. It is stated that the inductance is defined as the ratio between an electromotive impulsion and a current; we feel sure that in this country it is more often defined as the ratio between an e.m.f. and the rate of change of a current.

The first four pages give a useful historical background to the present position, and useful extracts from Professor Giorgi's 1934 memorandum describing the system and discussing the subject of dimensions.

We feel, however, that the question which is worrying people at the moment is not c.g.s. or m.k.s.—that is generally regarded as settled—but rationalization or

non-rationalization. The pamphlet concludes with the decision arrived at in 1938 at Torquay "that the question of rationalization should be left over for the time being, as it did not appear sufficiently ripe yet for the adoption of *final* conclusions." That was twelve years ago.

G. W. O. H.

The Electronic Engineering Master Index 1947-1948

Pp. 339 + xiii. Electronics Research Publishing Co. Inc., 480 Canal Street, New York 13, U.S.A. Price $19.50.

This index is to articles dealing with electronics and allied subjects which have appeared during 1947 and 1948 in the world's technical press. It includes also references to American, British and Canadian declassified documents covering some of the wartime research in electronics. American technical books are included and also patents.

The index is arranged under main subject headings and there is a cross index.

The Radio Amateurs' Handbook, 1950, 27th Edition

Pp. 615. The American Radio Relay League, West Hartford, Connecticut, U.S.A. Price $2.50.

Short-Wave Radio and the Ionosphere, 2nd Edition

By T. W. Bennington. Pp. 138 with 61 illustrations. Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 10s. 6d.

This book presents the available information on the ionosphere in simple form so that it is usable by non-specialists in the subject. The approach is non-mathematical.

Noise and Sound Transmission

Report of the 1948 Summer Symposium of the Acoustics Group. Pp. 200 + iv. The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7. Price 17s. 6d.

High Frequency Voltage Measurement

By Myron C. Selby. National Bureau of Standards Circular 481. Pp. 14 + ii. U.S. Government Printing Office, Washington 25, D.C., U.S.A. Price 20 cents, plus 1/3rd postage.

The Influence of a Single Echo on the Audibility of Speech

By H. Haas. Translated from German. Building Research Station, Department of Scientific and Industrial Research, Library Communication No. 363. Obtainable free by interested organizations and firms on written application to The Director, Building Research Station, Garston, Watford, Herts.

B.B.C. Television Service : A Technical Description

Pp. 32. British Broadcasting Corporation, The Grammar School, Scarle Road, Wembley, Middlesex. Price 2s.

A Home Built Frequency Modulated Receiver

By K. R. Sturley, Ph.D., M.I.E.E. Pp. 85. *Electronic Engineering*, 28 Essex Street, Strand, London, W.C.2. Price 4s. 6d.

Wireless at Sea

By H. E. Hancock. Pp. 233 + xxxiii. Marconi International Marine Communication Co. Ltd., Chelmsford. Price 15s.

17th NATIONAL RADIO EXHIBITION

This exhibition is being held on 6th-16th September at Birmingham and elaborate plans are being made for the demonstration of television receivers in operation. There will be a viewing hall where the different exhibits will be working side by side and, in addition, demonstrations will be made on the individual stands.

A studio will be provided in the exhibition, and will be open to inspection by the public and a film scanner will also be available. These two sources of programme will provide demonstration material outside the normal transmission hours of Sutton Coldfield. The programme from this station will, of course, be used when it is suitable.

The sound and vision signals will be 'piped' around the exhibition on carrier frequencies of 41.5 Mc/s and 45 Mc/s—the London frequencies. As a result all the receivers demonstrated will be London models. This is being done because it is impracticable to employ a local studio while Sutton Coldfield is operating if the distribution frequencies are the same as those of this station.

Some interference was experienced at the last London exhibition, although conditions there were less severe, and it is intended in future London exhibitions to adopt different carrier frequencies for distribution.

B.S.R.A. EXHIBITION

An exhibition is being organized by the British Sound Recording Association and will be held at the Waldorf Hotel, Aldwych, London, on 20th and 21st May. There is space for twenty exhibitors and for demonstrations in a separate hall. Mobile recording equipment, provided by the B.B.C., E.M.I., Pathé Pictures and M.S.S. Recording, will be shown.

The exhibition will be open from 2.30 to 6.0 on the 20th and from 10.30 to 6.0 on the 21st and admission will be by catalogue, price 1s.

INSTITUTION OF ELECTRICAL ENGINEERS

Meetings will be held at the I.E.E., Savoy Place, Victoria Embankment, London, W.C.2, on 18th May to commemorate the centenary of the birth of Oliver Heaviside. At 3 p.m. "Heaviside the Man" by Sir George Lee, O.B.E., M.C., followed at 5.30 by "An Appreciation of Heaviside's Contribution to Electromagnetic Theory" by Professor Willis Jackson, D.Sc., D.Phil.; "Heaviside's Operational Calculus" by Professor B. van der Pol, D.Sc.; "Fifty Years' Development in Telephone and Telegraph Transmission in Relation to the Work of Heaviside" by W. G. Radley, C.B.E., Ph.D. and "Some Unpublished Notes of Heaviside" by H. J. Josephs.

Radio Section Meeting

May 10th. "A Million-Volt Resonant-Cavity X-ray Tube," by B. Y. Mills, B.Sc., B.E. at 5.30 at I.E.E., London.

BRITISH INSTITUTE OF RADIO ENGINEERS

London Section. May 25th at 6.30 at London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1, "Multi Station V.H.F. Communication Systems Using Frequency Modulation," by E. G. Hamer and W. P. Cole, B.Sc.

ABSTRACTS and REFERENCES

Compiled by the Radio Research Board and published by arrangement with the Department of Scientific and Industrial Research

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of the titles of journals are taken from the World List of Scientific Periodicals. Titles that do not appear in this List are abbreviated in a style conforming to it.

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ACOUSTICS AND AUDIO FREQUENCIES

016 : 534 **1047**

References to Contemporary Papers on Acoustics.—A. Taber Jones. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, pp. 66–70.) Continuation of 521 of March.

534 : 061.3 **1048**

Subject Matter of the Acoustics Conference organized by the Acoustics Commission of the Academy of Sciences, U.S.S.R., Moscow, 26th February-1st March, 1949.—(*Bull. Acad. Sci. U.R.S.S., sér. phys.*, Nov./Dec. 1949, Vol. 13, No. 6, pp. 631–747. In Russian.) Report of 22 papers on various acoustical subjects presented at the conference. Many of the papers review Russian research in architectural acoustics, sound recording and reproduction, speech analysis, noise, etc.

534.131 **1049**

Acoustical Properties of Anisotropic Materials.—W. J. Price & H. B. Huntington. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, pp. 32–37.) Investigation of ADP and KDP single crystals by pulsed ultrasonic methods. Results are analysed.

534.231 + 538.566.2 **1050**

A New Method for Solving the Problem of the Field of a Point-Radiator in a Multilayer Nonuniform Medium.—Brekhovskikh. (*See* 1216.)

534.231 **1051**

The Sound Field near a Freely Oscillating Piston Membrane.—J. Meixner & U. Fritze. (*Z. angew. Phys.*, Dec. 1949, Vol. 1, No. 12, pp. 535–542.) The results of calculations for several wavelengths, of the order of magnitude of the membrane diameter, are presented graphically and compared with the sound field of an oscillating piston membrane in a rigid wall. The results are used to investigate the diffraction of a plane wave incident perpendicularly on a circular disk. For a wavelength about a third of the disk diameter, the sound fields of the incident and diffracted waves are determined, for both sides of the disk, and compared with approximations from Kirchhoff's diffraction theory. Comparison is also made between the sound field of a freely oscillating membrane and the lines of equal intensity behind a circular opening in a perfectly conducting plane on which a plane e.m. wave is incident perpendicularly.

534.26 **1052**

Variational Principles in Acoustic Diffraction Theory.—H. Levine. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, pp. 48–55.) "The diffraction of a plane harmonic sound wave by an aperture in an infinitely thin rigid plane screen is investigated theoretically. Variational principles for the diffracted spherical wave amplitude at large distances from the aperture are derived. In the first of these, the stationary property is exhibited for the class of functions comprising the normal derivative of the aperture velocity potentials, whose distributions are governed by a generally insolvable integral equation. The second involves functions which characterize the discontinuity in velocity potentials at the screen (or their deviation from infinite screen distributions), and are specified by another integral equation. A comparison of the two variational principles is given, which indicates that their over-all agreement, following use of approximate functions, is a measure of the accuracy obtained. The plane wave transmission cross section of the aperture is related to the imaginary part of the diffracted amplitude in the direction of incidence and is cast in stationary forms. Particular attention is given to the low and high frequency behavior of the various forms of cross section, including comparison with Kirchhoff theory predictions."

534.26 **1053**

The Diffraction of Sound by Rigid Disks and Rigid Square Plates.—F. M. Wiener. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, p. 47.) Correction to 3000 of 1949.

534.321.9 : 534.14 **1054**

Generation and Analysis of Ultrasonic Noise.—S. C. Ghose. (*Nature, Lond.*, 14th Jan. 1950, Vol. 165, No. 4185, pp. 66–67.) A brief description of apparatus used in the study of ultrasonic noise from turbo-jet engines. Special microphones and calibrating generators operating at frequencies up to 100 kc/s are described, and some details are given of a siren generator of ultrasonic noise of high intensity.

534.321.9 : 534.2 (26.03) **1055**

Transmission of 24-kc/s Underwater Sound from a Deep Source.—M. J. Sheehy. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, pp. 24–28.) Experimental methods are described. Preliminary results indicate that (*a*) the attenuation decreases with depth as both

transmitter and hydrophone are lowered from 150 to 1 000 ft, (*b*) the average attenuation below 350 ft is about 6 db per 1 000 yd, (*c*) the magnitude of the amplitude fluctuations of the directly transmitted signals increases roughly as the square root of the range, from about 10% at 100 yd to 45% at 3000 yd, (*d*) surface-reflected signals show greater fluctuations than the direct signals.

534.321.9 : 534.373 **1056**

Ultrasonic Absorption in Liquids.—G. W. Hazzard. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, pp. 29–32.) An experimental study of the effect of molecular asymmetry on absorption.

534.373 : 534.6 **1057**

Attenuation in a Rectangular Slotted Tube of (1,0) Transverse Acoustic Waves.—H. E. Hartig & R. F. Lambert. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, pp. 42–47.) Details are given of a pickup device for measuring the s.w.r. of transverse waves. Results for the frequency range 2 400–4 200 c/s are discussed.

534.6 : 621.395.6 **1058**

An Artificial Mouth for Acoustic Tests.—P. Chavasse. (*C. R. Acad. Sci., Paris*, 30th Jan. 1950, Vol. 230, No. 5, pp. 436–438.) Description of an artificial head which when used with an artificial voice (3404 of 1947) produces sounds which can with advantage replace the human voice in many tests of communication equipment.

534.61 + 534.85 **1059**

The Objective Measurement of Noise: its Possibilities and Limitations.—P. Baron. (*Ann. Télécommun.*, Oct. 1949, Vol. 4, No. 10, pp. 330–340.) A critical examination of various methods of measurement of noise intensity and a discussion of the merits of proposed methods based on the spectral distribution of energy.

534.612.4 **1060**

A Method for the Absolute Calibration of Sound Receivers by the Reciprocity Method.—M. V. Kazantseva. (*C. R. Acad. Sci. U.R.S.S.*, 11th Dec. 1947, Vol. 58, No. 8, pp. 1649–1651. In Russian.) Usually the absolute calibration of sound receivers is carried out in a free field and in chambers small in comparison with the sound wavelength. A method using a tube not shorter than half the sound wavelength is considered.

534.614 : 534.134 **1061**

A Crystal Pick-Up for Measuring Ultrasonic Wave Velocity and Dispersion in Solid Rods.—A. E. Bakanowski & R. B. Lindsay. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, pp. 14–16.) A description of a pickup which has been successfully applied to determine the internodal distances in a solid metal rod vibrating in resonance with the applied oscillator frequency. Accuracy is similar to that obtainable by the powder method; the pickup can be applied to cases for which that method is unsuitable.

534.64 **1062**

Reciprocity Pressure Response Formula which includes the Effect of the Chamber Load on the Motion of the Transducer Diaphragms.—M. S. Hawley. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, pp. 56–58.)

534.75 + 534.792 **1063**

The Masking of Pure Tones and of Speech by White Noise.—J. E. Hawkins, Jr, & S. S. Stevens. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, pp. 6–13.) The results of a study of monaural masking at eight sensation levels in the range 20–90 db.

534.771 **1064**

The Watch, as an Apparatus for Measuring Acuteness of Hearing.—P. Chavasse, R. Caussé & R. Lehmann. (*Ann. Télécommun.*, Dec. 1949, Vol. 4, No. 12, pp. 413–424.) The ticking of a watch is submitted to spectral analysis and its sound intensity and the principal components of the spectrum are considered. Different methods of noise measurement are compared. A watch affords a ready means for rapid measurements of hearing acuity; the physiological deductions which can be made from such measurements are discussed.

534.771 **1065**

A Method of Calculating Hearing Loss for Speech from an Audiogram.—H. Fletcher. (*J. acoust. Soc. Amer.*, Jan. 1950, Vol. 22, No. 1, pp. 1–5.)

534.83 : 84 : 061.3 **1066**

Symposium on Noise, London, 14th-19th July 1948.—P. Chavasse. (*Ann. Télécommun.*, Nov. 1949, Vol. 4, No. 11, pp. 377–382.) General comment on and review of the proceedings. 34 of the papers presented are listed with authors' names. 26 of these are summarized. They concern architectural acoustics; noise in aircraft, ships, and public halls; noise analysis; loudness measurement etc. See also 2115 of 1949 (Beranek).

534.85 : 621.396.645 **1067**

Phonograph Reproduction: Part 1.—McProud. (*See* 1117.)

621.395.61 **1068**

On the Application of Negative Feedback to Electro-acoustic Systems.—P. Chavasse & P. Poincelot. (*C. R. Acad. Sci., Paris*, 6th Feb. 1950, Vol. 230, No. 6, pp. 529–530.) The response curve of a reversible electrodynamic microphone was improved by the application of up to 32 db negative feedback.

621.395.623.7 **1069**

Duo-Cone Loud Speaker.—H. F. Olson, J. Preston & D. H. Cunningham. (*RCA Rev.*, Dec. 1949, Vol. 10, No. 4, pp. 490–503.) Full account of modifications of an earlier model which were noted in 17 of January.

621.396.645.37 : 621.395.623.7 : 621.3.018.8 **1070**

Output Impedance Control.—T. Roddam. (*Wireless World*, Feb. 1950, Vol. 56, No. 2, pp. 48–49.) A method is described for varying the damping of a loudspeaker without alteration of the output level. Negative voltage feedback is used to keep the amplifier gain constant while the output impedance is varied by positive current feedback.

621.395.623.7 + 534.85 **1071**

Sound Reproduction. (Book Review)—G. A. Briggs. Publishers: Wharfedale Wireless Works, Bradford, England and British Industries Corporation, 315 Broadway, New York 7, 1949, 143 pp., $2.95. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 236–237.) "The book consists of two major parts: Part I: Loudspeakers; Part II: Records. The part on loudspeakers extends the discussion of the previous book, 'Loudspeakers: The Why and How of Good Reproduction' (3333 of 1948) . . . The part on records surveys recording techniques and characteristics and discusses the various ills the art is heir to, such as tracking error, surface noise and motor rumble. The most interesting feature of the book from the reviewer's viewpoint is the series of photomicrographs, taken by C. E. Watts, of needles and grooves. The 200 × pictures show the effects of wear after various numbers of playings with different types of needles. They provide an excellent objective argument for using as hard a material for the tip of a pickup needle as possible."

AERIALS AND TRANSMISSION LINES

621.315.212 **1072**

Theory of the Coaxial Cable: Part 1.—F. Poliaczek. (*J. Phys. Radium*, July 1947, Vol. 8, No. 7, pp. 215–224.) By means of the ideas and methods of classical mathematical physics, making use of Green's functions, in-

tegral equations and developments in series, a rigorous theory of the coaxial cable in the periodic regime is established which is directly based on Maxwell's equations. A particular study is made of that part of the field which does not undergo exponential attenuation and which is completely neglected in the elementary theory of cables based on Kirchhoff's equations.

621.315.212 1073

Statistical Study of Irregularities in Coaxial Cables.—A. Sarti. (*Alta Frequenza*, Oct. 1949, Vol. 18, No. 5, pp. 195–204.)

621.392.21+621.392.26† 1074

Impedance of Resonant Transmission Lines and Wave Guides.—W. W. Harman. (*J. appl. Phys.*, Dec. 1949, Vol. 20, No. 12, pp. 1252–1255.) Universal curves relating the Q value and the resonance impedance of capacitively terminated transmission-line and waveguide sections are given and discussed. Their use in the design of cavity resonators and for determining resonator shunt resistance is considered.

621.392.26† 1075

The Excitation of a Circular Waveguide by a Ring Aerial.—A. Gaponov-Grekhov & M. Miller. (*Zh. tekh. Fiz.*, Nov. 1949, Vol. 19, No. 11, pp. 1269–1270. In Russian.)

621.392.26† 1076

Waveguide Field Patterns in Evanescent Modes.—A. L. Cullen. (*Wireless Engr*, Oct. 1949, Vol. 26, No. 313, pp. 317–322.) Field patterns in a waveguide at frequencies below cut-off are calculated, both for a single evanescent field, and for two oppositely attenuated ('incident' and 'reflected') fields. Isometric projection of the surface depicting the electric field in the guide is found to provide a useful picture of the field distribution.

621.392.26† 1077

Application of Picard's Method of Successive Approximations to the Study of Discontinuities in Waveguides.—T. Kahan. (*C. R. Acad. Sci., Paris*, 6th Feb. 1950, Vol. 230, No. 6, pp. 527–529.) A general solution of the problem of the echo pattern in a waveguide having a slight nonuniformity. The solution is given in the form of an infinite series converging more rapidly the smaller the nonuniformity.

621.392.26† : 538.566 1078

On the Theory of the Propagation of Electromagnetic Waves in Tubes with Abruptly Varying Cross-Sections.—G. V. Kisun'ko. (*C. R. Acad. Sci. U.R.S.S.*, 11th Dec. 1947, Vol. 58, No. 8, pp. 1653–1656. In Russian.) A mathematical investigation of the propagation of e.m. waves, without reflection, through joints between two waveguides or through a combination of elements such as diaphragms, transformers and other similar devices.

621.392.26† : 621.315.611 1079

An Investigation of Dielectric Rod as Wave Guide.—C. H. Chandler. (*J. appl. Phys.*, Dec. 1949, Vol. 20, No. 12, pp. 1188–1192.) An experimental investigation indicates that the guiding effect is retained even when the rod is only a fraction of a wavelength in diameter. The greater part of the guided energy is then outside the dielectric, so that a very-low-loss waveguide results. Measurements at a wavelength of 1.25 cm indicate attenuations down to 0.004 db/m in polystyrene rod and show good agreement with theoretical predictions. A resonator using a dielectric-rod waveguide is described; this has a maximum Q of about 53 000.

621.392.26† : 621.315.611 1080

Attenuation in a Dielectric Circular Rod.—W. M. Elsasser. (*J. appl. Phys.*, Dec. 1949, Vol. 20, No. 12, pp. 1193–1196.) Analysis is given of the non-radiating modes propagated along a cylindrical dielectric rod, with discussion of dielectric loss. The attenuation for the three lowest modes in a rod of polystyrene is computed; the results agree with the values found experimentally by Chandler (1079 above).

621.392.5 : 621.392.26† 1081

Microwave Directional Couplers.—S. Freedman. (*Radio & Televis. News, Radio-Electronic Engng Supplement*, Feb. 1950, Vol. 14, No. 2, pp. 11–13, 25.) An illustrated description of various types of waveguide coupling and their use in microwave measurements.

621.396.67 1082

The Concept of an Angular Spectrum of Plane Waves, and its Relation to that of Polar Diagram and Aperture Distribution.—H. G. Booker & P. C. Clemmow. (*Proc. Instn elect. Engrs*, Part III, Jan. 1950, Vol. 97, No. 45, pp. 11–17.) "A critical examination is made of the somewhat loose and incomplete statement that a polar diagram is the Fourier transform of an aperture distribution. By aperture distribution it is necessary to understand, in the two-dimensional case, distribution across the aperture of the component along the aperture plane of the electromagnetic field in the plane of propagation. Furthermore, the concept of the polar diagram has to be replaced by that of an angular spectrum, except in the common case when the aperture may be considered more or less limited in width, and the field is being evaluated at a point whose distance from the aperture is large compared with the width of the aperture (and the wavelength). For example, it is convenient for some purposes to regard the problem of diffraction of a plane wave by a semi-infinite plane screen, with a straight edge, as a problem about an aperture distribution in the plane of the screen. This is a case for which the concept of a polar diagram is not in general applicable, and has to be replaced by that of an angular spectrum. The field at all points in front of a plane aperture of any distribution may be regarded as arising from an aggregate of plane waves travelling in various directions. The amplitude and phase of the waves, as a function of their direction of travel, constitutes an angular spectrum, and this angular spectrum, appropriately expressed, is, without approximation, the Fourier transform of the aperture distribution. If the aperture distribution is of such a nature that the concept of the polar diagram is applicable at sufficiently great distances, then the polar diagram is equal to the angular spectrum. But the angular spectrum is a concept that is always applicable, whereas the polar diagram is one that is liable to be invalid (for example, in the Sommerfeld theory of propagation over a plane, imperfectly reflecting earth)."

621.396.67 1083

Constructing Helical Antennas.—E. D. Smith. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 72–75.) Construction details are given for several helical aerials suitable for the 435-Mc/s amateur band and for citizens' radio on 465 Mc/s. A simple impedance-matching unit for coaxial-cable feeder is also described.

621.396.67 : 530.1 1084

Electromagnetic Similitude: General Principles and Application to the Study of the Aerial.—S. Colombo. (*Ann. Télécommun.*, Nov. 1949, Vol. 4, No. 11, pp. 370–376.)

621.396.67 : 621.397.62 1085

Trends in TV Receiver Antenna Design.—I. Kamen. (*TV Engng, N.Y.*, Jan. 1950, Vol. 1, No. 1, pp. 8–11.) A critical analysis, with illustrations, of eight types of aerial particularly suitable for vision and sound reception in the U.S.A.

621.396.671 1086

Gain of Aerial Systems.—D. A. Bell. (*Wireless Engr*, Nov. 1949, Vol. 26, No. 314, p. 380.) Correction to 3057 of 1949.

621.396.671 1087

Impedance/Frequency Characteristics of Some Slot Aerials.—J. W. Crompton. (*Proc. Instn elect. Engrs*, Part III, Jan. 1950, Vol. 97, No. 45, pp. 39–44.) Measurements were made by the earth-plane method, using a coaxial standing-wave indicator, of the input impedance near half-wave resonance of (*a*) simple centre-fed slot aerials of various widths, (*b*) two dumb-bell slot aerials, (*c*) an end-fire slot aerial, over the frequency range 130–370 Mc/s.

621.396.677 1088

The Design of Metallic Delay Dielectrics.—J. Brown. (*Proc. Instn elect. Engrs*, Part III, Jan. 1950, Vol. 97, No. 45, pp. 45–48.) "A theory of metallic delay dielectrics, which is more accurate than existing ones and is based on an analogy with shunt-loaded transmission lines, has been developed for the simplest case, when the delay medium consists of an array of infinitely long conducting strips. Formulae have been obtained for the refractive index, impedance and cut-off wavelength of such a medium, and the more important results are presented graphically. A procedure for designing such dielectrics to have a desired refractive index is outlined, and some limitations in the use of metallic delay lenses are pointed out."

621.396.67 1089

Radio Aerials. (Book Review.)—E. B. Moullin. Publishers: Oxford University Press, London, 514 pp., 50s. (*Wireless World*, Feb. 1950, Vol. 56, No. 2, p. 70.) "The first section of the book is theoretical. The Lorentz vector and scalar retarded potential functions are first established and then applied to specific problems. These include the fields due to filaments, the effect of flat-sheet and V-shaped reflectors, and problems relating to cylinders immersed in electromagnetic fields.

Some hypothetical problems are solved rigorously, usually in terms of Bessel functions, and practical problems are considered as approximations—usually very close ones—to the hypothetical cases. The power gain of typical arrays with various current distributions is calculated, and methods of suppressing the side-lobes discussed. A short section is devoted to the isolated aerial.

The remaining one-third of the book describes experimental procedure, and the results of measurements made on some of the aerials described in the first section. Results for V aerials are given in great detail, and include the radiation patterns for various V angles and sizes of sheet."

Attention is drawn to many practical design considerations, such as the permissible tolerance on reflector shape, the use of netting and rods instead of continuous sheet, and similar problems. "The treatment is mainly mathematical" and the book "will therefore appeal more to the aerial specialist or post-graduate student". It "will be found valuable not only as a book of reference on the types of aerial covered, but also for the clear and logical development of the general theory".

CIRCUITS AND CIRCUIT ELEMENTS

621.318.572 1090

Direct-Reading Electronic Timer.—R. R. Freas. (*RCA Rev.*, Dec. 1949, Vol. 10, No. 4, pp. 554–566.) "The application of resistance-coupled multivibrators to binary and decade counter chains is described, with suggestions for improved stability. Several independent counts may be selected and registered on counter dials from one continuously operating electronic counter with the coincidence indicator circuits shown. The electronic counter may be automatically reset to zero or any advance count with the reset circuit presented." Applications to loran receivers are mentioned.

621.318.572 : 621.317.755.087 1091

A Beam-Switching Circuit.—R. Milne. (*Electronic Engng*, Feb. 1950, Vol. 22, No. 264, pp. 54–56.) A trigger circuit with particular application to the recording of transient effects. The beam of a c.r.o. is switched on for a single sweep of the timebase.

621.318.572 : 621.385.3 : 621.315.59 1092

Counter Circuits using Transistors.—E. Eberhard, R. O. Endres & R. P. Moore. (*RCA Rev.*, Dec. 1949, Vol. 10, No. 4, pp. 459–476.) A flip-flop circuit using two transistors is compared with the Eccles-Jordan circuit and its use in a decade counter is described. A flip-flop circuit using a single transistor is analysed and stability limits with respect to load resistance and transistor parameters are indicated; practical component values are given for this circuit, which can be operated up to 500 kc/s. Transistor relaxation oscillators have been synchronized in a frequency divider which converts from 100 kc/s to 25 c/s and operates from a 45-V supply, from which it takes 675 mW. Present transistors are unstable with time and temperature and differ widely in characteristics and hence cannot yet be used for reliable counting.

621.392.4 1093

Constant-Phase-Shift Networks.—W. Saraga. (*Wireless Engr*, Nov. 1949, Vol. 26, No. 314, p. 380.) Comment on 3078 of 1949 (Rowlands).

621.392.43 1094

Theoretical Limitations on the Broadband Matching of Arbitrary Impedances.—R. M. Fano. (*J. Franklin Inst.*, Jan. 1950, Vol. 249, No. 1, pp. 57–83.) Technical Report No. 41, Massachusetts Institute of Technology, Research Laboratory of Electronics.

621.392.43 1095

Impedance Matching using a Special Type of Exponential Line.—A. Niutta. (*Poste e Telecomunicazioni*, Aug. 1949, Vol. 17, No. 8, pp. 417–423.) For matching low-impedance lines to aerials with high input impedance. Formulae are derived from which the dimensions of a suitable 4-wire exponential line can be calculated. This line is inserted between half-section high-pass filters. Measurements show that the impedance remains satisfactorily uniform over the frequency range 4–24 Mc/s. A numerical example illustrates the method.

621.392.5 1096

The Solution of Linear-Network Problems by the Method of Nodal Equations.—M. Soldi. (*Alta Frequenza*, Oct. 1949, Vol. 18, No. 5, pp. 213–231.) The practical advantages of the method are illustrated. Suitable equivalent networks are shown for valves, transformers and, in particular, the ideal transformer.

621.392.5 1097

Contribution to the Theory of Networks.—M. Prudhon & P. M. Prache. (*Ann. Télécommun.*, Jan. 1948, Vol. 3, No. 1, pp. 24–30.) Relations are established between the impedances of the various branches and the coefficients of the link and nodal equations. Formulae are then derived from which the nodal equations may be simply obtained when the parts of the network are connected by mutual-impedance coupling. Simple applications of the formulae to a transformer and to a valve are given.

621.392.5.018.1 : 621.396.615 **1098**

The Effect of Valve Impedance on Phase-Shift Oscillators.—R. Townsend. (*Electronic Engng*, March 1950, Vol. 22, No. 265, pp. 116–117.) Comment on 840 of April. Curves are given for the frequency and attenuation constants in 3-section and 4-section RC networks and also CR networks.

621.392.52 **1099**

Dissipative Band-Pass Filters.—F. Juster. (*Radio prof., Paris*, Jan. 1950, Vol. 19, No. 180, pp. 28–30.) Formulae are given for practical application of the methods of design given by Dishal (3369 of 1949).

621.392.52 **1100**

Filters: Part 2.—"Cathode Ray". (*Wireless World*, Feb. 1950, Vol. 56, No. 2, pp. 61–65.) Discussion of the properties of filters, using the simplest possible mathematics. Part 1: 578 of March.

621.392.53 : 621.3.015.3 **1101**

The Exact Solution for Transient Distortion in Networks.—D. C. Espley. (*Electronic Engng*, March 1950, Vol. 22, No. 265, pp. 82–87.) Paper presented at the 1948 Television Congress, Paris. Summary noted in 652 of 1949. A rigorous and systematic method of distortion correction in electrical networks. The distorting system is represented by a hypothetical simulating network defined entirely in terms of input and output waveforms. The input waveform is considered as a pulse with an energy content appropriate to the expected frequency range of the transmission path, and the output waveform as the desired signal appearing after the nominal propagation time and followed by a finite series of echoes defined by amplitude, time and sign. The correction network is derived by inversion from the distortion simulating network and the passage of the distorted output current through it will produce across its terminals a voltage of the original undistorted form.

621.396.611.1.015.3 : 621.3.012 **1102**

Detuned Resonant Circuits.—H. Elger. (*Wireless Engr*, Nov. 1949, Vol. 26, No. 314, pp. 360–364.) A method of calculating or graphically tracing the transients in such circuits is shown in connection with a simple memory rule. The application of the method to similar mechanical and supersonic problems is considered. The real response of resonant circuits when using p.m. or any other kind of shock excitation (such as static), the change of time constant due to detuning, and the signal/noise ratio are considered.

621.396.611.3 : 517.2/.3 **1103**

Time-Constant Selection in the Application of RC Differentiating and Integrating Circuits.—R. J. Jeffries. (*Instruments*, Dec. 1949, Vol. 22, No. 12, p. 1106.) The performance of the basic circuit for both operations is presented graphically in terms of M (the product of R in ohms, C in farads and f in c/s) and the phase characteristic. The useful operating ranges of the circuit are found for values of M less than about 0.01 for differentiation and greater than about 3.0 for integration. Numerical examples are given.

621.396.611.4 **1104**

On the Characteristics of Electromagnetic Resonant Cavities formed by Two Concentric Spheres.—J. Broc. (*C. R. Acad. Sci., Paris*, 9th Jan. 1950, Vol. 230, No. 2, pp. 198–199.) For resonance on a fixed wavelength in the magnetic mode, the outer radius (R_2) of such a cavity is greater than that of a completely hollow sphere resonant on the same wavelength, and as the ratio $s(= R_1/R_2)$ approaches unity, $R_2 \to \infty$. For the electric mode, R_2 is less than the radius of the equivalent hollow sphere and approaches a finite limit, not zero, as the ratio s tends to unity. Calculated values of R_2 and Q for λ 10 cm are tabulated for values of s ranging from 0 to 1.

621.396.611.4 **1105**

On the Variation of the Natural Frequency of Cavity Resonators formed by Concentric Spheres, for Small Displacements of the Inner Sphere.—J. Broc. (*C. R. Acad. Sci., Paris*, 16th Jan. 1950, Vol. 230, No. 3, pp. 285–286.) For the H_{11a} mode, a displacement ε produces a reduction Δf of the natural frequency f_0, such that $\Delta f/f_0 = -2(\varepsilon/R_2)^2/(1 - s^2)^2$, where $s = R_1/R_2$ and R_1 and R_2 are the radii of the inner and outer spheres respectively. For larger displacements ($\varepsilon/R_2 > 0.01$) the approximations used in the derivation of this expression do not hold. See also 1104 above.

621.396.615 **1106**

Operating Conditions for Cathode-Coupled Flip-Flops.—D. W. Thomasson; J. D. Storer. (*J. Brit. Instn Radio Engrs*, Jan. 1950, Vol. 10, No. 1, pp. 12–14.) Comment of 3083 of 1949 (Storer) and Storer's reply. The conditions for oscillation and the effects of using different component values are discussed.

621.396.615 : 621.396.611.21 **1107**

A High-Stability Quartz Oscillator.—M. Indjoudjian. (*Onde élect.*, Feb. 1950, Vol. 29, No. 275, pp. 76–78.) The oscillator is basically a 2-stage amplifier with negative feedback. A Y-cut 100-kc/s crystal vibrating longitudinally couples the anode circuit of the second valve to the grid of the first valve. In this grid circuit is a thermistor indirectly heated by the feedback current from the output transformer secondary; its resistance varies in value from 50 kΩ when cold to 500 Ω during normal working. Variations of oscillation amplitude and of supply voltages produce negligible phase change. The short-period stability during a year's test was $< \pm 0.5 \times 10^{-7}$ and the monthly drift of the order of 1×10^{-7}. The tests included deliberate valve changing and stoppages. The method of frequency checking is described.

621.396.615.14 : 621.385.18 **1108**

Plasma Oscillator.—G. Wehner. (*J. appl. Phys.*, Jan. 1950, Vol. 21, No. 1, pp. 62–63.) R.f. oscillations are found to occur in low-pressure arc-discharge tubes in which a repelier electrode is inserted in the electron beam between the grid and anode. The resonant circuits are formed by thin oscillation layers inside the plasma. The oscillations are of well-defined frequency, tunable between 1 kMc/s and 4 kMc/s by changing the anode voltage and current. They occur in different modes; a relation is given between beam velocity, frequency and mode number for a typical tube construction.

621.396.615.14.029.63 **1109**

New U.H.F. Oscillator.—D. H. Preist. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 120 . , 162.) Advantages claimed for this circuit, which largely resembles a grounded-grid amplifier, are that a wide range of adjustment of phase and amplitude of the feedback is available, adjustments are simple to make, and power-handling capacity is high. Satisfactory results are obtained at frequencies from below 100 Mc/s to over 2 kMc/s at power levels up to many kilowatts.

621.396.615.17 **1110**

Asymmetrical Multivibrators.—R. Feinberg. (*Wireless Engr*, Oct. 1949, Vol. 26, No. 313, pp. 325–330.) "The frequency and the waveform of oscillation of an asymmetrical multivibrator with pentodes can be computed with the help of simple formulae provided the circuit is so designed that one of the two anode voltages is of rectangular or near-rectangular shape

when the multivibrator is in the steady state of operation. The waveform of the other anode voltage may be rectangular or triangular and may be varied within a fairly wide range without interfering with the frequency of oscillation. The frequency of oscillation may be altered without disturbing the waveform by changing the capacitance values but keeping their ratio constant. Predicted frequencies and waveforms are verified by experiment."

621.396.615.17 1111

The Miller Circuit as a Low-Speed Precision Integrator.—I. A. D. Lewis. (*Electronic Engng*, Feb. 1950, Vol. 22, No. 264, pp. 60–68.) Errors caused by drifts, by nonlinearity in time (assuming all the circuit elements to be linear) and by the operation of resetting between cycles of integration, are considered in some detail. The analysis includes the effects of stray capacitance in the circuit and is, therefore, also applicable to high-speed integrators.

621.396.615.17 : 621.317.755 1112

A Self-Adjusting Time-Base Circuit.—H. Asher. (*Electronic Engng*, Feb. 1950, Vol. 22, No. 264, pp. 61–65.) A type of timebase in which the only frequency control is a range switch which selects one of three wide frequency ranges. Inside these ranges, the frequency of the timebase will be rigidly locked to that of the signal, and at the same time the amplitude of the timebase sweep voltage will remain constant.

621.396.615.18.029.64 1113

Microwave Frequency Dividers.—H. Lyons. (*J. appl. Phys.*, Jan. 1950, Vol. 21, No. 1, pp. 59–60.) Methods of division for frequencies up to 20 kMc/s or more are of importance for applications such as atomic clocks. A regenerative-modulator type of circuit dividing from 9.3 kMc/s to 3.1 kMc/s is described; tests show that the output is one-third of the input frequency to an accuracy within one part in 10^{10}. This circuit uses klystron multiplier and amplifiers, and the amplifiers are needed to work only at the output frequency and not at the higher input frequency. A modified circuit is proposed in which the regenerative-modulator divider is provided with a second regenerative channel and thus provides its own input. A suggested arrangement for an atomic oscillator and clock is described. Suitable equipment for this method, using the ammonia line at 24 kMc/s, is being investigated, but alternatively a convenient line at about 9 kMc/s could be used.

621.396.645 1114

Stagger-Tuned Low-Pass Amplifiers.—W. E. Thomson. (*Wireless Engr*, Nov. 1949, Vol. 26, No. 314, pp. 357–359.) The method of design of band-pass amplifiers by stagger-tuning, in its wider sense, may be simply extended to low-pass amplifiers to specify the frequency response. The determination of networks with the desired frequency response presents a fresh problem. Suitable networks are given for a multistage low-pass amplifier with a gain, as a voltage ratio, of $g_m/\omega_0 C$ per stage, a bandwidth of $\omega_0/2\pi$ c/s, or slightly more, and a reasonably flat pass-band; g_m is the mutual conductance of the valves used, ω_0 the nominal bandwidth and C the interstage capacitance.

621.396.645 1115

The Cathode-Follower Output Stage.—R. M. Mitchell. (*Audio Engng*, N.Y., Feb. 1950, Vol. 34, No. 2, pp. 12–13, 32.) Advantages and disadvantages are discussed.

621.396.645 1116

On the Input and Output Admittances of Amplifiers.—L. Vallese. (*Alta Frequenza*, Oct. 1949, Vol. 18, No. 5, pp. 205–212.) The input and output admittances of linear amplifiers can be represented by means of networks consisting of the passive quadripole equivalent circuit with the addition of appropriate series or parallel elements the admittances of which are functions of the amplification factor. The consideration of such networks gives a clear picture of the working of the amplifier.

621.396.645 : 534.85 1117

Phonograph Reproduction: Part 1.—C. G. McProud. (*Audio Engng*, N.Y., Feb. 1950, Vol. 34, No. 2, pp. 24–31.) Discussion of the design of a control unit for use with the musician's amplifier (70 of January). Needle scratch is effectively reduced.

621.396.645.029.3 1118

Push-Pull A.F. Amplifiers.—K. R. Sturley. (*Wireless Engr*, Oct. 1949, Vol. 26, No. 313, pp. 338–343.) "Problems of the position of the composite load line and the construction of the valve load curves for classes A, B and C audio-frequency push-pull amplifiers are discussed and it is shown that B. J. Thompson's original work on class-B amplifiers with matched valves can be extended to cover all classes of push-pull amplification under matched or unmatched conditions. Deductions regarding composite and valve-load curves as a result of voltage and current measurements are confirmed by photographs of valve-load curves obtained on the screen of a cathode-ray tube."

621.396.645.029.3 1119

Study of a High-Quality Voltage Amplifier.—J. Mey. (*Ann. Télécommun.*, Nov. 1949, Vol. 4, No. 11, pp. 383–384.) Description of a 5-stage audio amplifier, with circuit diagram and performance figures. It has low distortion and background noise, high and linear gain, and satisfactory stability with normal supply-voltage variations.

621.396.645.029.4/.52 : 621.396.822 1120

Selective Amplification at Low Frequencies.—L. de Queiroz Orsini. (*Onde élect.*, Feb. 1950, Vol. 29, No. 275, pp. 91–102.) For parts 1 and 2 see 596 of March. Part 3 describes the apparatus, method and results of measurement of flicker effect. The following conclusions are drawn: (*a*) the current due to shot effect in saturated diodes is well represented by Macfarlane's equation (4087 of 1947); (*b*) at l.f. tungsten filaments are much better than oxide-coated filaments; (*c*) the presence of space charge does not affect the spectral distribution of noise; (*d*) the equivalent resistance of the l.f. noise in triodes and the noise voltage at the grid are given by simple formulae and can be calculated approximately from the values given for certain parameters.

621.396.645.35 1121

A D.C. Amplifier using an Electrometer Valve.—D. H. Peirson. (*Electronic Engng*, Feb. 1950, Vol. 22, No. 264, pp. 48–53.) Description, with circuit details, of a balanced d.c. amplifier of the bridge type in which the controls are reduced to the minimum required for zero-balancing by use of a highly stable power pack. Under these conditions external temperature variation exerts a limiting effect upon amplifier stability. The effect is minimized by using a new indirectly-heated double electrometer valve, Type DHM8A, which has a temperature coefficient not greater than 0.2 mV/°C, a grid current of about 3×10^{-15} A and grid insulation, when carefully cleaned, $>10^{16}\,\Omega$.

621.396.645.3 : 621.317.39 1122

A D.C. Amplifier with Cross-Coupled Input.—J. N. Van Scoyoc & G. F. Warnke. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 104–107.) A compact unit with cross-coupled input stage for use with either single-ended or push-pull circuits. Two amplification stages, with a cathode-follower output and feedback amplifier, provide an output of 310 V peak-to-peak to feed a c.r. tube. Gain is variable in 20 steps of 2 db from a maximum of

90 ohms. Input impedance is 100 MΩ and frequency response extends from zero to 61 kc/s. A preamplifier has a maximum usable gain of about 250 000.

621.396.645.371 **1123**

Negative-Feedback Amplifiers.—C. F. Brockelsby. (*Wireless Engr*, Nov. 1949, Vol. 26, No. 314, p. 380.) Reply to comment by McLeod (3111 of 1949) on 2768 of 1949.

621.396.69 **1124**

New Radio Components in the World Market.—M. Alixant. (*Radio tech. Dig., Édn franç.*, Feb. 1950, Vol. 4, No. 1, pp. 3–41.) New edition of 2770 of 1949 and including, in addition, resistors, potentiometers, RC subassemblies, and materials. Most of the novelties brought out since the last Paris Salon de la Pièce détachée are noted.

GENERAL PHYSICS

530.081 : 621.3.081 **1125**

The Introduction of the Giorgi System of Units.—H. König, M. Krondl & M. Landolt. (*Tech. Mitt. schweiz. Telegr.-Teleph.Verw.*, 1st Dec. 1949, Vol. 27, No. 6, pp. 257–278. In French and German.) A general discussion of the system and its practical application. Tables are included giving the corresponding values of all the principal electrical quantities in the c.g.s. e.m. and e.s. systems and in the Giorgi system, with conversion factors.

530.1 : 621.396.67 **1126**

Electromagnetic Similitude: General Principles and Application to the Study of the Aerial.—S. Colombo. (*Ann. Télécommun.*, Nov. 1949, Vol. 4, No. 11, pp. 370–376.)

537.212 **1127**

Effect of an Arbitrary Field on a Sphere or on a Circular Cylinder.—E. Durand. (*C. R. Acad. Sci., Paris*, 9th Jan. 1950, Vol. 230, No. 2, pp. 188–190.) A solution of the Laplace equation which is constant over the conductor. Analogous solutions for a dielectric sphere or cylinder are obtained.

537.533 **1128**

Production and Application of Directional Electron Beams.—A. A. Rusterholz. (*Bull. schweiz. elektrotech. Ver.*, 4th Feb. 1950, Vol. 41, No. 3, pp. 65–77. In German, with French summary.) The development of high-power electron guns is principally a question of design. The efficiency of such systems is limited by certain factors, of which the effect of space charge is of major importance. Approximate methods of investigating the effect of these factors are examined. The best solution of the problem at present appears to be that proposed by Pierce (1419 and 4275 of 1940), which greatly simplifies calculation. As an example, the design of the electron injector for a betatron is considered.

538.114 **1129**

Physical Theory of Ferromagnetic Domains.—C. Kittel. (*Rev. mod. Phys.*, Oct. 1949, Vol. 21, No. 4, pp. 541–583.) Survey of domain theory and of the crucial experiments relating to it. The interpretation of coercive force, reversible permeability, hysteresis and the Barkhausen effect is outlined in terms of domains. The theoretical analysis of domain energy is discussed and expressions are given for the exchange, magnetocrystalline, magnetoelastic and magnetostatic energy components. The properties of the Bloch wall, across which the spin direction in adjacent domains reverses, are reviewed. Various domain structures are considered theoretically and compared with experimental data derived from magnetic powder pattern technique in which a thin liquid layer containing a colloidal suspension of a fine ferromagnetic powder is applied to the surface of the sample. The single domain behaviour of small particles is described; the dependence of initial permeability and coercive force on nonuniformities of the material is outlined.

538.566 **1130**

The Symmetrical Excitation of an Infinitely Long Dielectric Cylinder.—B. Z. Katsenelenbaum. (*Zh. tekh. Fiz.*, Oct. 1949, Vol. 19, No. 10, pp. 1168–1181. In Russian.) A mathematical investigation of the e.m. oscillations due to excitation of the cylinder by an elementary dipole mounted on the axis.

538.566 **1131**

The Asymmetrical Oscillations of an Infinitely Long Dielectric Cylinder.—B. Z. Katsenelenbaum. (*Zh. tekh. Fiz.*, Oct. 1949, Vol. 19, No. 10, pp. 1182–1191. In Russian.) A mathematical investigation of free and forced e.m. oscillations due to excitation by an elementary dipole.

538.566 **1132**

On the Focusing of a Wave.—J. Ortusi & J. C. Simon. (*C. R. Acad. Sci., Paris*, 6th Feb. 1950, Vol. 230, No. 6, pp. 521–523.) The conditions under which focusing occurs are discussed. The focusing obtained by phase displacement at surfaces with circular holes is contrasted with optical focusing by means of lenses. Experiments with 8-cm waves are briefly described.

539 **1133**

On the Asymptotic Distribution of Eigenvalues.—J. S. de Wet & F. Mandl. (*Proc. roy. Soc. A*, 22nd Feb. 1950, Vol. 200, No. 1063, pp. 572–580.) Application of the methods of Courant & Hilbert leads very simply to a proof that the asymptotic distribution of the eigenvalues of the one-dimensional Schrödinger equation is given by the W.K.B. formula. Analogous formulae are also found for the 2- and 3-dimensional equations.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.7 **1134**

A Tentative Model of the Sun.—R. H. Woodward. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 387–396.)

523.72 **1135**

Investigations of Solar Radiation by the Brazil Expedition of the Academy of Sciences of the U.S.S.R. for Observing the Solar Eclipse of 20th May 1947.—S. E. Khaykin & B. M. Chikhachev. (*C. R. Acad. Sci. U.R.S.S.*, 21st Dec. 1947, Vol. 58, No. 9, pp. 1923–1926. In Russian.) A report on observations made in a ship off the Brazilian coast. The results are plotted and discussed; they show (*a*) that the minimum r.f. radiation intensity of the eclipsed sun is about 40% of that when the sun is not eclipsed, (*b*) that the variation of the intensity is displaced with regard to the geometrical eclipse. It is concluded that the observed r.f. radiation is generated in the upper layers of the sun's atmosphere not covered by the moon's shadow, and that the radiation intensity is not uniformly distributed over the surface of the radiating sphere.

523.72 : 621.396.81 **1136**

Solar Noise and Ionospheric Fading.—Smith-Rose. (*See* 1228.)

523.746 **1137**

On the Mathematical Characteristics of Sunspot-Variations.—A. F. Cook. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 347–354.) New relations among the monthly relative numbers and their maxima and minima are applied to Stewart & Panofsky's formula to compute a new family of curves. See also 3454 of 1939 (Stewart & Eggleston).

523.746"1949.07/.09" 1138

Provisional Sunspot-Numbers for July to September, 1949.—M. Waldmeier. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, p. 398.)

538.12 : 521.15 1139

The Fundamental Relation between the Magnetic Moment and the Structure of Rotating Celestial Bodies.—H. P. Berlage. (*Nature, Lond.*, 11th Feb. 1950, Vol. 165, No. 4189, pp. 242–243.) Simple derivation of Blackett's formula, assuming that celestial bodies possess a nucleus from which free electrons migrate into the outer shell more easily than positive ions.

550.38"1949.04/.06" 1140

International Data on Magnetic Disturbances, Second Quarter, 1949.—J. Bartels & J. Veldkamp. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 399–400.)

550.38"1949.07/.09" 1141

Cheltenham (Maryland) Three-Hour Range Indices *K* for July to September, 1949.—R. R. Bodle. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, p. 398.)

550.384 1142

Sudden Commencements in Geomagnetism: their Dependence on Local Time and Geomagnetic Longitude.—V. C. A. Ferraro & W. C. Parkinson. (*Nature, Lond.*, 11th Feb. 1950, Vol. 165, No. 4189, pp. 243–244.) Preliminary analysis of data from six observatories.

550.385"1949.04/.09" 1143

Principal Magnetic Storms (April–Sept. 1949).—(*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 401–402.)

551.508.1 : 551.594.11 1144

A Radiosonde Method for Potential-Gradient Measurements in the Atmosphere.—Kreielsheimer. (*See* 1204.)

551.510.535 1145

Ionosphere Review: 1949.—T. W. Bennington. (*Wireless World*, Feb. 1950, Vol. 56, No. 2, pp. 53–56.) Sunspot cycle and s.w. propagation survey, with forecast for 1950.

551.510.535 1146

The Problem of the Ionospheric Regions.—M. Nicolet. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 373–381. In French, with English summary.) The dissociation and ionization processes in the upper atmosphere due to solar radiation are discussed. Assumptions are made as to the scale height and molecular density at different heights and the most likely processes assigned to each layer. Molecular and atomic oxygen are the main sources of ions in the E and F_1 regions respectively. In the F_2 region atomic nitrogen and oxygen are both important and their relative concentrations are deduced. The conditions under which molecular nitrogen is important are discussed.

551.510.535 1147

On Investigations of the F_2 Layer of the Ionosphere during the Total Solar Eclipse of 20th May, 1947.—Ya. L. Al'pert. (*C. R. Acad. Sci. U.R.S.S.*, 21st Dec. 1947, Vol. 58, No. 9, pp. 1919–1922. In Russian.) Using pulse equipment previously described (2093 of 1947), observations of the F_2 layer of the ionosphere were carried out in Brazil from 17th to 24th May inclusive. Measurements of the effective height of the layer were made at a frequency of 9.5 Mc/s. In addition, measurements were made at various times at frequencies from 5 to 15 Mc/s. The results obtained are plotted and discussed. One of the conclusions reached is that in addition to variations in the ionization, a considerable expansion of the layer took place during the eclipse. It is considered that measurements of critical frequencies only are not sufficient for studying the properties of the layer. See also 2893 of 1946.

551.510.535 1148

Nocturnal Ionization in the F_2 Ionospheric Region.—N. C. Gerson. (*Rev. mod. Phys.*, Oct. 1949, Vol. 21, No. 4, pp. 606–624.) The structure and composition of the earth's atmosphere to a height of 300 km are reviewed and also the photochemical and photoionization processes which occur in sunlight. Whereas the Chapman model accounts well for the E region and roughly for the F_1 region, it is not relevant to the F_2 region. A study of the various oxygen and nitrogen reactions shows that the F_2 region should dissipate during darkness at a greater rate than is observed; consideration is given to possible non-solar sources of ionization and of these only meteoric bombardment is likely to be significant. Examination of the vertical, horizontal and turbulent transportation of ions suggests that these may be important in maintaining the nocturnal ion concentration in the F_2 layer.

551.510.535 1149

The Distribution of Atomic and Molecular Oxygen in the Upper Atmosphere.—R. Penndorf. (*Phys. Rev.*, 15th Feb. 1950, Vol. 77, No. 4, pp. 561–562.)

551.510.535 1150

Electron Diffusion in the Ionosphere.—R. Seeliger. (*Ann. Phys., Lpz.*, 1st Aug. 1948, Vol. 3, pp. 297–304.) Discussion of ionosphere structure and the layer theory. The lack of sufficient reliable observations prevents definite conclusions being drawn.

551.510.535 1151

Stratification of the F_2-Layer of the Ionosphere over Singapore.—Hon Yung Sen. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 363–366.) Measurements during January and February, 1946, indicated that the F_2 layer was daily stratified into three discrete layers during the daylight hours. Typical daytime h'/f and diurnal-variation curves are reproduced.

551.510.535 1152

Analysis of Virtual-Height/Frequency Records.—U. C. Guha. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 355–362.) For a Chapman layer an approximate expression is derived for virtual height h' at frequency f as a function of f/f_c, where f_c is the critical frequency. The fit is very close both for the theoretical Chapman distribution and also for experimental h'/f curves for the F_2 region with and without a retarding E region. The extension to non-Chapman distributions is discussed.

551.510.535 : 551.506.2 1153

Ionosphere and Weather.—E. Gherzi. (*Nature, Lond.*, 7th Jan. 1950, Vol. 165, No. 4184, p. 38.) Discussion of weather forecasting based on a correlation, as yet unexplained, between the usual ionosphere echoes and the movement of polar, maritime and equatorial air masses. See also 2771 of 1947.

551.510.535 : 621.396.11 1154

Calculation of the Absorption Decrement for a Parabolic Ionospheric Layer in the case of Oblique Incidence.—É. Argence & K. Rawer. (*C. R. Acad. Sci., Paris*, 2nd Jan. 1950, Vol. 230, No. 1, pp. 69–70.) A treatment of the problem by geometrical optics to derive a final expression for the case of reflection. See also 627 of March.

551.510.535 : 621.396.11 1155

Manifestations of the Sporadic-E Layer on Metre Waves in 1949, and Observation of a Concomitant Noise.—Revirieux. (*See* 1222.)

551.510.535 : 621.396.11 1156

Sporadic Ionization at High Latitudes.—J. H. Meek. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 339–345.) See 725 of March.

551.510.535 : 621.396.11 1157

Effect of the D-Ionospheric Layer on Very Low Frequency Radio Waves.—W. Pfister. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 315–337.) See 723 of March.

551.510.535 : 621.396.812.3 1158

The Analysis of Observations on Spaced Receivers of the Fading of Radio Signals.—Briggs, Phillips & Shinn. (*See* 1233.)

LOCATION AND AIDS TO NAVIGATION

621.396.93 1159

Rotating Aerial for an Automatic Radiogoniometer.—P. Rodez. (*Ann. Télécommun.*, Oct. 1949, Vol. 4, No. 10, pp. 341–346.) Theory and principle of operation of a system comprising three vertical $\lambda/4$ dipoles asymmetrically spaced at the corners of a horizontal triangle and turning together on a vertical axis. A field-strength pattern with a single sharp minimum is obtained. An experimental model operating on 120 Mc/s gave satisfactory results. Sensitivity is about the same as with A/cock systems.

621.396.932.1/.2 1160

A New Direct-Reading Loran Indicator for Marine Service.—F. E. Spaulding, Jr. & R. L. Rod. (*RCA Rev.*, Dec. 1949, Vol. 10, No. 4, pp. 567–585.) The pulse rate of the receiver-indicator is automatically controlled by means of a pulse-phase discriminator and a reactance valve which correct the frequency of the receiver's 100-kc/s crystal oscillator. Frequency division from 100 kc/s is performed by binary and decade counters using double-triode trigger circuits (see 1090 above); any one of 24 station pulse rates may be selected. After matching the pulses on the screen of a 3-in. c.r. tube, time-difference readings are directly displayed on a five-digit dial. An extra sweep is available for self-checking the performance and accuracy; the error due to signals differing in amplitude by as much as 10:1 : 1, with 10-V maximum peak signal, does not exceed 0.5 μs.

621.396.933 1161

Electronic Aids to Air Navigation.—A. A. McK. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 66–71.) Elementary and brief accounts of the principal features of various navigation aids now in use or about to be used in U.S. civil aircraft. These include compass systems, direction finders, radio ranges, distance measuring equipment, approach and landing equipment, and markers.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.37 1162

On the Kinetics of the Luminescence of Sulphide Phosphors with Several Activators.—M. Schön. (*Ann. Phys., Lpz.*, 1st Aug. 1948, Vol. 3, pp. 333–342.)

535.37 1163

Note on the Width of the Emission Bands of Sulphide Phosphors.—M. Schön. (*Ann. Phys., Lpz.*, 1st Aug. 1948, Vol. 3, pp. 343–344.)

535.37 1164

Effect of Temperature on the Extinction of the Luminescence of Sulphides by Electric Fields.—J. Mattler. (*C. R. Acad. Sci., Paris*, 2nd Jan. 1950, Vol. 230, No. 1, pp. 76–77.)

537.58 : 539.234 1165

Thermionic Emission of Thin Films of Alkaline Earth Oxide Deposited by Evaporation.—G. E. Moore & H. W. Allison. (*Phys. Rev.*, 15th Jan. 1950, Vol. 77, No. 2, pp. 246–257.) Monomolecular films of BaO and SrO on tungsten and molybdenum surfaces are shown to give thermionic emissions of the same magnitude as commercial oxide-coated cathodes. The effect is qualitatively explained by considering the adsorbed molecules as oriented dipoles, and the theory is compared with the semiconductor theory for bulk oxide coatings. Full experimental details are given.

538.221 1166

Saturation Magnetization of Certain Ferrites.—L. Néel. (*C. R. Acad. Sci., Paris*, 9th Jan. 1950, Vol. 230, No. 2, pp. 190–192.) A study of the different affinities of the divalent M ion in ferrites of the type Fe_2O_3MO, from consideration of the energy expended in movement of the M ion from an octahedric to a tetrahedric position. A formula for the magnetic moment at saturation at absolute zero of the Fe_2O_3MO molecule gives results in good agreement with experiment for ferrites in which M is replaced by Mn, Fe, Co, Ni, Cu or Zn. See also 3159 of 1949.

538.221 1167

Spontaneous Magnetization of Ferromagnetic Ferrites of Spinel Structure.—E. W. Gorter. (*C. R. Acad. Sci., Paris*, 9th Jan. 1950, Vol. 230, No. 2, pp. 192–194.) Experimental results which verify Néel's theory (1166 above).

538.221 1168

Magnetization Curves and Energies, Coercive Field and Magnetostriction of a Ferrite of Cobalt [vectolite].—C. Guillaud, R. Vautier & S. Medvedieff. (*C. R. Acad. Sci., Paris*, 2nd Jan. 1950, Vol. 230, No. 1, pp. 60–62.)

538.221 1169

On the Decrease of the Thermo-Remanent and Isothermally-Remanent Magnetizations of Fired Earths by Reheating at Successively Higher Temperatures.—J. Roquet. (*C. R. Acad. Sci., Paris*, 16th Jan. 1950, Vol. 230, No. 3, pp. 282–285.) See also 902 of April.

538.221 1170

The Molecular-Field Coefficients for Mixed Ferrites of Nickel and Zinc.—L. Néel & P. Brochet. (*C. R. Acad. Sci., Paris*, 16th Jan. 1950, Vol. 230, No. 3, pp. 280–282.)

538.221 1171

Saturation Magnetization of Mixed Ferrites of Nickel and Zinc.—L. Néel. (*C. R. Acad. Sci., Paris*, 23rd Jan. 1950, Vol. 230, No. 4, pp. 375–377.) Some experimental results are interpreted satisfactorily by the author's theory (1166 above and 3159 of 1949).

538.221 : 621.318.323.2.042.15 1172

Effective Permeability and Q Factor of Magnetic Powders.—A. Colombani. (*C. R. Acad. Sci., Paris*, 6th Feb. 1950, Vol. 230, No. 6, pp. 523–525.) A derivation of general formulae.

538.221.029.64 1173

The Properties of Ferromagnetic Compounds at Centimetre Wavelengths.—J. B. Birks. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 65–74.) Measurements of the magnetic and dielectric properties of γ-Fe_2O_3, Fe_3O_4, Mn/Zn and Ni/Zn ferrites at wavelengths in the range 60–1.23 cm are described and discussed.

538.222 1174

Magnetic Properties of Palladium Alloys.—J. Wucher. (*C. R. Acad. Sci., Paris*, 14th Dec. 1949, Vol. 229, No. 24, pp. 1309–1310.) Results of measurements of the paramagnetism of alloys of Pd with Cu, Ag, Au, Al, Sn, Pb and Al, and comparison with results for Ni alloys.

1175

539.23 : 537.311.1

The Resistivity of Thin Metallic Films.—R. A. Weale. (*Proc. phys. Soc.*, 1st Feb. 1949, Vol. 62, No. 350A, pp. 135–136.) A formula is derived for the effective temperature coefficient (α) of resistance of thin films; this shows that α is zero for a particular thickness of any given material and that it should be negative for smaller thicknesses. It is to be expected that α will be negative for comparatively thick films of Bi, in which metal the mean free path of the electrons is exceptionally long. The results of van Itterbeek & de Greve on Ni films (1305 of 1946) are in good agreement with the formula given.

1176

546.287 : 621.315.61

Silicones: Composition; Properties; Applications.—G. Regert-Monod & P. Seguin. (*Ann. Télécommun.*, Dec. 1949, Vol. 4, No. 12, pp. 431–440.) A comprehensive study of commercial silicones.

1177

546.821 : [537.533 + 621.3.011.2

The Physical Properties of Titanium: Part 1 — Emissivity and Resistivity of the Commercial Metal.—W. C. Michels & S. Wilford. (*J. appl. Phys.*, Dec. 1949, Vol. 20, No. 12, pp. 1223–1226.)

1178

549.514.51 : 621.924

Mechanical Production of Very Thin Oscillator Plates.—L. T. Sogn & W. L. Howard. (*Bur. Stand. J. Res.*, Nov. 1949, Vol. 43, No. 5, pp. 459–464.) The thickness at which the crystal carrier stretches or buckles is the limiting factor in conventional apparatus. To produce quartz oscillator plates thinner than 0.005 in. (i.e. for operation above 14 and 20 Mc/s for AT and BT cuts respectively) the usual lapping methods and machinery have been modified by replacing the conventional top lapping plate and changing the crystal carrier correspondingly. The development of different methods is traced from the simple pressure-block method to the more elaborate forms using automatic truing. The improved equipment is capable of producing quartz crystals 0.001 in. thick, and equally thin wafers of other materials. For a shorter account see *Radio & Televis. News, Radio-Electronic Engng Supplement*, Feb. 1950, Vol. 14, No. 2, pp. 7, 30.

1179

620.197 : 621.314.2

Some Mechanical Aspects of Hermetically Sealed Transformer Technique.—C. Evans. (*J. Brit. Instn Radio Engrs*, Jan. 1950, Vol. 10, No. 1, pp. 20–36.) A discussion of the problems of sealing oil-filled and air-filled transformers, and of practical methods recently used.

1180

621.319.4 : 620.197.119

Hermetic Sealing of Capacitors.—P. R. Coursey. (*Proc. Instn elect. Engrs*, Part III, Jan. 1950, Vol. 97, No. 45, pp. 56–64.) A review of the development of modern types of terminal insulation.

1181

669.15.26 : 666.1.037.5 : 621.385.832

The Evaluation of Chromium-Iron Alloys for Metal Kinescope Cones.—A. S. Rose & J. C. Turnbull. (*RCA Rev.*, Dec. 1949, Vol. 10, No. 4, pp. 593–599.) Description of tests to determine the suitability of Cr:Fe alloys for sealing to the glasses used in the production of c.r. tubes with metal cones.

MATHEMATICS

1182

517.432.1

Justification of Heaviside Methods.—J. J. Smith & P. L. Alger. (*Elect. Engng, N.Y.*, Feb. 1950, Vol. 69, No. 2, p. 116.) Summary of A.I.E.E. 1949 Summer Meeting paper. The Schwartz method of representing a discontinuous function as a distribution in mass-space gives equations exactly parallel to those obtained by use of Heaviside's method.

1183

681.142

Static Magnetic Storage and Delay Line.—An Wang & Way Dong Woo. (*J. appl. Phys.*, Jan. 1950, Vol. 21, No. 1, pp. 49–54.) "Magnetic cores with a rectangular hysteresis loop are used in a storage system which requires no mechanical motion and is permanent. The binary digit '1' is stored as a positive residual flux, and the binary digit '0' as a residual flux in the opposite direction. When a negative probing field is applied to the core, a large voltage is induced in another winding if the digit stored has been a '1', and very small voltage if it has been a '0'. The induced voltage in the former case is large enough to magnetize another core of identical construction. Binary digits can thus be transferred from one core into another. Many cores are arranged in tandem to form an information delay line. Binary digits can be advanced along the line step by step. The present upper limit of the speed of propagation is about 35 000 digits per second, and there is no lower limit."

1184

681.142

Use of the Relay Digital Computer.—E. G. Andrews & H. W. Bode. (*Elect. Engng, N.Y.*, Feb. 1950, Vol. 69, No. 2, pp. 158–163.) The machine whose use is described is the Bell Telephone Laboratories Model V computer. Control is by perforations on teletype tapes. Illustrative applications include binomial expansions in probability theory, and the solution of ordinary and partial differential equations. A simple example of coding is given. For efficient operation, problems should be repetitive.

MEASUREMENTS AND TEST GEAR

1185

531.76

On the Use of Crystal Controlled Synchronous Motors for the Accurate Measurement of Time.—V. E. Hollinsworth. (*Canad. J. Res.*, Dec. 1949, Vol. 27, Sec. F, No. 12, pp. 470–478.) An illustrated description of an electronic frequency converter which uses a 1 kc/s supply controlled by the 50-kc/s quartz frequency standard of the Dominion Observatory to derive sufficient power for operating several standard 60-c/s motors. These are used for driving drum chronographs and other recorders. Circuit diagrams are given of the 100-c/s and the 10-c/s frequency dividers, the 60-c/s frequency multiplier, the 60-c/s power amplifier and the supply unit.

1186

621.317.2.089.6

A Royal Air Force Calibration Centre.—W. H. Ward and the Staff of the Measurements Division, T.R.E. (*Proc. Instn elect. Engrs*, Part III, Jan. 1950, Vol. 97, No. 45, pp. 49–55.) Discussion of the general principles governing the planning of a centre for maintaining the calibration of R.A.F. radio and radar test equipment, and some details of the methods and apparatus used.

1187

621.317.3.029.5/.6

Measurements at Radio Frequencies.—G. A. Day. (*Aust. J. Instrum. Tech.*, Sept. 1949, Vol. 5, No. 5, pp. 190–210.) Outline of r.f. methods used for the measurement of various electrical quantities.

1188

621.317.73.029.62/.63

Discontinuities in Concentric-Line Impedance-Measuring Apparatus.—M. H. Oliver. (*Proc. Instn elect. Engrs*, Part III, Jan. 1950, Vol. 97, No. 45, pp. 29–38.) Three methods of investigating such discontinuities are described: (*a*) the narrow-band frequency-variation method; (*b*) the wide-band frequency-variation method; (*c*) the reactance-variation method. The last method has certain advantages. The effect of discontinuities on the measurement of resistance and reactance, of conductance and susceptance, and of cable characteristics, is discussed and practical measurement techniques are suggested.

621.317.733.083.4 1189

Differential-Amplifier Null Detector.—M. Conrad. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 96–97.) The advantages of this instrument are reduction in weight and cost, very high input impedance, guarded shielding, and adaptability to very low frequencies where transformers are not advantageous. On the other hand, it requires balancing and in general it is more complex than a transformer. When used as a null-detector for an equal-arm a.c. resistance bridge, the instrument will detect an unbalance of less than 0.1%, and the discrimination against common-mode signals is greater than 70 db.

621.317.77 1190

An Improved Audio-Frequency Phase Meter.—O. E. Kruse & R. B. Watson. (*Audio Engng, N.Y.*, Feb. 1950, Vol. 34, No. 2, pp. 9–11, 46.) The instrument described can be used to measure without ambiguity the phase angle between two sinusoidal signals in the frequency range 40 c/s to 29 kc/s with an error $<2°$. Up to 20 kc/s the error is $<1°$. An alternative circuit arrangement overcomes the instability of reading which normally occurs in a phase meter when the phase angle is very near 0° or 360°.

621.317.78.029.65 1191

Discrepancies in the Measurement of Microwave Power at Wavelengths below 3 cm.—J. Collard, G. R. Nicoll & A. W. Lines. (*Proc. phys. Soc.*, 1st March 1950, Vol. 63, No. 363B, pp. 215–216.) Measurements of 20-mW power were made at T.R.E. for the wavelength range 7.5–12.5 mm, using (*a*) a water calorimeter, (*b*) an enthrakometer (2020 of 1948), (*c*) a thermistor bead. More accurate comparisons between enthrakometer and thermistor for a power of 1 mW and wavelength of 9 mm, and between enthrakometer and calorimeter for a power of 50 mW and the same wavelength, were consistent with the direct comparison of all three instruments. The results obtained with the enthrakometer and the calorimeter agreed to within a few per cent, but the readings given by the thermistor were only about half those obtained by the other two methods. Thermistor beads of a particular type give fairly consistent results, so that it may be possible to dispense with individual calibration and apply a simple correction factor.

621.396 : 621.3.018.4(083.74) 1192

British Standard-Frequency Transmissions.—(*R.S. G.B. Bull.*, Feb. 1950, Vol. 25, No. 8, p. 264.) Daily transmissions, arranged by the Department of Scientific and Industrial Research, commenced on 1st February 1950 from the G.P.O. station at Rugby on frequencies of 60 kc/s (1029 to 1045 GMT), 5 Mc/s (0544 to 0615 GMT) and 10 Mc/s (0629 to 0700 GMT). The transmitter power in each case is 10 kW. The frequencies are maintained within 2 parts in 10^8 of the nominal frequencies and are monitored at the National Physical Laboratory. The transmissions are arranged in cycles of 15 minutes, each starting with a 1-minute transmission of the Morse call sign MSF, with spoken announcements; the carrier wave is then modulated at 1 000 c/s for 5 minutes and is unmodulated for the remaining 9 minutes. 1-c/s pulses will at some future date be added during the first 5 minutes of the unmodulated transmission. See also 134 of 1949.

621.396.662.029.6 1193

Calibrated Piston Attenuator.—A. C. Gordon-Smith. (*Wireless Engr*, Oct. 1949, Vol. 26, No. 313, pp. 322–324.) The attenuator, which operates in the evanescent H_{11} or TE_{11} circular mode, consists of a pair of telescopic brass tubes. "The outer tube has a diameter such that when filled with air the attenuation is about 7 db per mm. The inner tube is filled with polystyrene and acts as a non-attenuating waveguide for the H_{11} mode but does not transmit other modes. The attenuation per mm of movement has been measured, after frequency conversion, in terms of a standard piston attenuator and agreement obtained between the measured and theoretical values within the limits of experimental accuracy. It has also been confirmed that the crystal mixer and its associated circuit is a linear converter at a wavelength of 6 mm."

621.397.62.001.4 1194

Measurement of Transient Response of TV Receivers.—J. Van Duyne. (*TV Engng, N.Y.*, Jan. 1950, Vol. 1, No. 1, pp. 14–18.) Discussion of the requirements of measurement equipment for studying the electrical fidelity of the picture channel, and description of suitable apparatus. 60 c/s, 2.4 kc/s and 94.5 kc/s are selected as the repetition rates for the rectangular test signals.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.767 1195

Gas-Flow Speedometer.—G. L. Mellen. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 80–81.) Measurement of the transit time of an ion cloud in the gas over a known distance gives rate of flow without introducing impurities. Range of speeds is 20–400 m.p.h.

534.321.9 : 616.36-073 1196

Lupam — an Ultrasonoscope Locator for Medical Applications.—R. P. McLoughlin & G. N. Guastavino. (*Rev. telegr., Buenos Aires*, Sept. 1949, Vol. 38, No. 444, pp. 507–517, 543.) Basic principles for such units are reviewed, and equipment is described in which the reflection of ultrasonic pulses is applied to locate gallstones or other small objects. C.r.o. presentation similar to type-A radar display is used. Calibration methods are indicated.

538.569.2.047 : 621.38 1197

Dielectric Properties of Some Animal Tissues at Meter and Centimeter Wave Lengths.—E. R. Laird & K. Ferguson. (*Canad. J. Res.*, Nov. 1949, Vol. 27, Sec. A, No. 6, pp. 218–230.) Measurements of the dielectric constant and the absorption coefficient of different tissues, using wavelengths of 1.72 m, 9.5 cm and 3.2 cm. For most of the substances tested the dielectric constant decreased considerably with increasing frequency; the absorption, on the other hand, increased largely.

539.16.08 1198

Photomultipliers for Scintillation Counting.—G. A. Morton. (*RCA Rev.*, Dec. 1949, Vol. 10, No. 4, pp. 525–553.) A review of various commercially available multipliers and discussion of their characteristics.

539.16.08 1199

A Stabilizer for Proportional Counters.—D. H. Wilkinson. (*J. sci. Instrum.*, Feb. 1950, Vol. 27, No. 2, pp. 36–38.) The introduction of an α-particle group into a counter enables high precision to be attained over long periods by deriving control of the voltage applied to the counter from this group. Theory of the method is given and a suitable circuit is described.

539.16.08 1200

A Portable Geiger Counter.—M. Michaelis & R. O. Jenkins. (*Electronic Engng*, March 1950, Vol. 22, No. 265, pp. 112–115.) Detailed description of equipment including a standard G.E.C. Type G.M.2 or G.M.4 self-quenching tube and suitable for either β-, γ- or X-ray detection.

539.16.08 1201

Temperature Effects in the Spurious Discharge Mechanism of Parallel-Plate Counters.—F. L. Hereford. (*Phys. Rev.*, 15th Feb. 1950, Vol. 77, No. 4, pp. 559–560.)

539.16.08 : 547.211 1202

Effect of Light on a Diamond Conduction Counter.—R. K. Willardson & G. C. Danielson. (*Phys. Rev.*, 15th Jan. 1950, Vol. 77, No. 2, pp. 300–301.) The accumulation of space charge field resulting from the trapping of charge carriers reduces the rate of counting. The effect may be completely eliminated in some diamonds by irradiation with violet light. After treatment the diamond is in an activated condition and the counting rate is maintained indefinitely. The effect is thus different from the ordinary release of space charge by red light, which has only a temporary effect on the counting rate.

539.16.08 : 615.849 1203

Geiger-Müller Tubes in Industrial Radiography.—O. J. Russell. (*Electronic Engng.*, March 1950, Vol. 22, No. 265, pp. 94–98.)

551.508.1 : 551.594.11 1204

A Radiosonde Method for Potential-Gradient Measurements in the Atmosphere.—K. Kreielsheimer. (*The New Zealand Science Congress*, 1947, pp. 91–98.) Details of modifications of the Bureau of Standards radiosonde (315 of 1941) to adapt it for recording potential gradients, and discussion of results obtained. A preliminary account was noted in 1955 of 1946 (Kreielsheimer & Belin).

621.318.572 1205

An Electrical Transient Display System.—J. A. Lyddiard & J. W. Osselton. (*J. sci. Instrum.*, Feb. 1950, Vol. 27, No. 2, pp. 38–41.) Description of apparatus designed to facilitate the observation of transients in networks including iron-cored reactors operated at 50 c/s, by providing a succession of identical transients which can be viewed for any length of time on the screen of a c.r.o. Electronic methods are used. Switching cycles are accurately controlled. The equipment can also be used to generate square waves of very low frequency.

621.38.001.8 : 578.088.7 1206

An Electronic Stimulator for Biological Research.—V. H. Attree. (*J. sci. Instrum.*, Feb. 1950, Vol. 27, No. 2, pp. 43–47.) Circuit details and operation of a 0.005–500-c/s generator with three outputs simultaneously available, one providing exponential pulses, the other two giving square pulses.

621.38.001.8 : 616-07 1207

Electronic Instruments in Diagnostic Medicine.—H. A. Hughes. (*Electronic Engng.*, Feb. & March 1950, Vol. 22, Nos. 264 & 265, pp. 43–47 & 88–93.) Discussion of equipment for electroencephalography, electrical stimulation, electrocardiography, etc.

621.384.6 1208

Phase Focusing in Linear and in Spiral Accelerators.—W. Dällenbach. (*Amer. Phys., Lpz.*, 1st Aug. 1948, Vol. 3, pp. 89–100.)

621.384.611.1 1209

Betatrons with and without Iron Yoke.—A. Bierman & H. A. Ockle. (*Philips tech. Rev.*, Sept. 1949, Vol. 11, No. 3, pp. 65–78.) The fundamental principles of the betatron are outlined, with a description of two recently constructed machines. One, on conventional lines, uses an iron circuit for the magnetic field, with 500-c/s a.c. excitation, and accelerates electrons to 5 MeV. In the second apparatus the magnetic field is obtained by means of coils through which the discharge current from a battery of capacitors flows. A small iron core weighing only 5 kg is used. The flux, being obtained from damped oscillations, at a frequency of 2 500 c/s, reaches the required intensity only during the first few cycles of each discharge and thus the output from the apparatus is pulsed. Electron energies of 9 MeV are obtained. The practical elimination of iron in this model results in a very great saving in weight. See also 2015 of 1949 (Bierman).

621.385.833 1210

The Field in an Electron-Optical Immersion Objective.—L. Jacob. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 75–83.)

621.385.833 1211

Electron Optical Mapping of Electromagnetic Fields.—L. Marton & S. H. Lachenbruch. (*J. appl. Phys.*, Dec. 1949, Vol. 20, No. 12, pp. 1171–1182.) See also 967 of April.

621.385.833 1212

Fringe Fields of Ferromagnetic Domains.—L. Marton, S. H. Lachenbruch, J. A. Simpson & A. Van Bronkhorst. (*J. appl. Phys.*, Dec. 1949, Vol. 20, No. 12, p. 1258.) Photographs showing (*a*) the distorted mesh pattern due to the fringe field along the edge of a cobalt single crystal, (*b*) the pattern obtained with a small $BaTiO_3$ crystal, using the new "shadow" technique (199 of January), are briefly discussed.

621.385.833 1213

On the Theory of the Independent Electrostatic Lens with Three Diaphragms.—E. Regenstreif. (*C. R. Acad. Sci., Paris*, 14th Dec. 1949, Vol. 229, No. 24, pp. 1311–1313.) Formulae are derived which give results in good agreement with experiment and permit accurate determination of the voltage which must be applied to the central diaphragm to convert the lens into a reflector.

621.385.833 : 669 1214

Metallurgical Applications of the Electron Microscope.—(*Engineering, Lond.*, 9th & 16th Dec. 1949, Vol. 168, Nos. 4376 & 4377, pp. 625 & 652.) Report of the meeting organized by the Institute of Metals in November 1949, with summaries of 13 papers presented and of the discussions on them. See also *Nature, Lond.*, 11th March 1950, Vol. 165, No. 4193, pp. 390–393.

621.398 1215

Remote Control by A.F. Discrimination.—R. B. McNeil. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 142–150.) The equipment is designed to have a bandwidth no greater than that used for normal a.m. communications, and considerably simplified control equipment, which comprises a tone-modulated transmitter at each master station, and an amplifier-relay unit at each of the relay stations, operating in conjunction with a receiver and constant-output amplifier. The modulator unit may be used for voice modulation of the transmitter. The equipment operates well through interfering signals and noise.

PROPAGATION OF WAVES

538.566.2 : 534.231 1216

A New Method for Solving the Problem of the Field of a Point-Radiator in a Multilayer Nonuniform Medium.—L. M. Brekhovskikh. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, July/Aug. 1949, Vol. 13, No. 4, pp. 409–420. In Russian.) The theory of propagation of waves in multilayer media is important not only for electromagnetic but also for sound waves, especially when the latter are propagated in the sea, where ducts may be formed. In this paper the field due to a point-radiator of either electromagnetic or sound waves is investigated mathematically. The spherical wave is resolved into a number of plane waves which are integrated in a complex plane.

1217

538.566.2

The Reflection of Plane Waves from Multilayer Non-Uniform Media.—L. M. Brekhovskikh. (*Zh. tekh. Fiz.*, Oct. 1949, Vol. 19, No. 10, pp. 1126–1135. In Russian.) Mathematical analysis for multilayer media with arbitrary variation of the parameters. The theory proposed is not based on the wave equation but on an equation of the first order of the reflection coefficient. Two methods of successive approximations are indicated for expressing the reflection coefficient in the form of convergent series. An example shows the rate of convergence of these series.

1218

538.566.2

Application of Huyghens' Principle to Refraction. Expressions for the Reflected and Refracted Waves.—J. Brodin. (*C. R. Acad. Sci., Paris*, 2nd Jan. 1950, Vol. 230, No. 1, pp. 67–69.)

1219

621.396.11 : 535.4

On the Diffraction of Radar Waves by a Semi-Infinite Conducting Screen.—C. W. Horton & R. B. Watson. (*J. appl. Phys.*, Jan. 1950, Vol. 21, No. 1, pp. 16–21.) Measurements of the diffraction patterns of cm waves at the edge of a semi-infinite copper screen are described. A receiving horn was revolved about the centre of the edge at a radius of 15 in. or 30 in. and angles of incidence upon the screen of 0° and −22½° were investigated. The results are shown as polar diagrams, which agree well with theoretical patterns.

1220

621.396.11 : 551.510.535

Ionospheric Cross-Modulation at Oblique Incidence.—L. G. H. Huxley. (*Proc. roy. Soc. A*, 22nd Feb. 1950, Vol. 200, No. 1063, pp. 480–511.) Systematic investigation of ionospheric cross-modulation, using selected pairs of B.B.C. transmitters in special night-time tests. Evidence supports the assumption that the seat of cross-modulation is highly localized in the E region, in one or two regions near the lower of the surfaces of reflection of the wanted and disturbing waves. The quantities measured are Gv, (v is the mean electron collision frequency and G a constant for the gas at the seat of cross-modulation) and T_0, the percentage transferred modulation depth at "zero" modulation frequency. Nocturnal and seasonal changes in these quantities are discussed. An estimate is made of the gradients of electron concentration and collision frequency at a height of about 86 km.

1221

621.396.11 : 551.510.535

Discussion of the Ionosphere Reflection Factor. Scattering of Ground-Wave Energy and its Conversion into Space-Wave Energy.—C. Glinz. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st Dec. 1949, Vol. 27, No. 6, pp. 279–283. In German.) Methods of calculating the reflection coefficient are discussed. Vilbig (887 of 1939) considers that a relation exists between this coefficient and ground conductance. It seems that such a relation can only be apparent, since in the wavelength range 200–2000 m ionospheric absorption cannot be neglected. From the C.C.I.R. field-strength curves it can only be deduced with certainty that the indirect radiation reaches a maximum for distances of 400–600 km. In the area covered by the direct radiation of a transmitter, part of the energy is scattered by irregularities of the ground. Such scattering increases the ratio of space-wave to ground-wave energy, so that modifications of a transmitting aerial designed to reduce the ratio do not result in the calculated improvement in reception. The ground wave undergoes no appreciable dispersion when propagation is over the sea. This may partly explain the dependence of the indirect radiation on the ground conductance.

1222

621.396.11 : 551.510.535

Manifestations of the Sporadic-E Layer on Metre Waves in 1949, and Observation of a Concomitant Noise.—P. Revirieux. (*C. R. Acad. Sci., Paris*, 9th Jan. 1950, Vol. 230, No. 2, p. 200.) Manifestations were frequent in June/July on 50–52 Mc/s. 18th June is cited as a favourable example. After 1700 GMT, a 100-W transmitter at Oslo produced a field strength at Meudon of above 100 μV/m on 50.1 Mc/s. Other distant stations were heard. During this time a characteristic noise was received on 145 Mc/s, using a Yagi aerial with 4 horizontal elements. The noise level was some 5–10 db above that of the receiver. The direction of the noise source coincided with that of the E_s layer causing the long-range reception on 50 Mc/s.

1223

621.396.11 : 551.510.535

Effect of the D Ionospheric Layer on Very-Low-Frequency Radio Waves.—W. Pfister. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 315–337.) See 723 of March.

1224

621.396.11 : 551.510.535

Sporadic Ionization at High Latitudes.—J. H. Meek. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 339–345.) See 725 of March.

1225

621.396.11 : 551.510.535

Calculation of the Absorption Decrement for a Parabolic Ionospheric Layer in the case of Oblique Incidence.—Argence & Rawer. (*See* 1154.)

1226

621.396.11 : 621.396.81

A Relation between the Sommerfeld Theory of Radio Propagation over a Flat Earth and the Theory of Diffraction at a Straight Edge.—H. G. Booker & P. C. Clemmow. (*Proc. Instn elect. Engrs.*, Part III, Jan. 1950, Vol. 97, No. 45, pp. 18–27.) The field strength at a point above an imperfectly reflecting flat earth, due to vertically polarized radiation from a line source parallel to the earth's surface, is considered as that due to reflection by a perfectly conducting earth added to that due to the Zenneck wave diffracted, in the two-dimensional case, under the image line. For the three-dimensional case, the diffraction would be through a slot extending downwards from the image point. For points well above the earth's surface this diffracted wave is the edge-wave from the diffracting edge. The field strength is then the same as calculated on the ray theory with the ordinary Fresnel image of the source in the imperfectly conducting source. For points close to the earth's surface, the diffracted wave must be calculated using the Fresnel integral. This gives the Sommerfeld formula for propagation over a flat earth. The advantages of this derivation of Sommerfeld's formula in considering propagation over a land/sea boundary are briefly indicated.

1227

621.396.11.029.55

New Observations on the Doppler Effect in the Propagation of Decametre Radio Waves.—B. Decaux & M. Crouzard. (*C. R. Acad. Sci., Paris*, 12th July 1948, Vol. 227, No. 2, pp. 116–117.) From observations in Paris of the standard-frequency transmissions from Washington on 5, 10, 15 and 20 Mc/s from the 12th to 15th April 1948 between 0800 and 2200 GMT, and from former observations (1725 of 1948), the mean values of frequency variation during 24 hours are plotted. A positive maximum appears during sunrise over the propagation path; a corresponding frequency minimum occurs during sunset. The maximum frequency changes range from 5×10^{-8} at 20 Mc/s to 20×10^{-8} at 5 Mc/s. Between 1400 and 1500 GMT and at 0200 GMT no variation is observed.

621.396.81 : 523.72 1228

Solar Noise and Ionospheric Fading.—R. L. Smith-Rose. (*Nature, Lond.*, 7th Jan. 1950, Vol. 165, No. 4184, pp. 37–38.) Solar noise measurements at Slough on 30, 42, 73 and 155 Mc/s, made simultaneously with field-strength measurements of signals from South Africa and Germany on 18.89 Mc/s and 191 kc/s, show that bursts of noise are frequently accompanied by a fade-out of the h.f. signal and a marked fluctuation in level of the l.f. signal.

An outstanding example, which occurred on 21st May 1948, is discussed in detail; the variation of the l.f. signal is characteristic of interference between ground and ionosphere waves caused by a change in phase and amplitude of the latter. This can be explained by a change in the equivalent height of reflection, together with an increase in the effective reflection coefficient of the ionosphere.

621.396.81 : 551.510.535 1229

Field Intensity at the Receiver as a Function of Distance.—P. Lejay & D. Lepechinsky. (*Nature, Lond.*, 25th Feb. 1950, Vol. 165, No. 4191, pp. 306–307.) A graphical method is described for finding, from a vertical-incidence $h'f$ trace, the virtual path followed by a wave reflected obliquely from the ionosphere. A reflectrix, or locus of the reflection point for the virtual ray as the angle of incidence is varied, can be found by a simple graphical construction if a plane earth is assumed. For a curved earth and curved ionosphere a more laborious method, not described, must be used. From the shape of the reflectrix the field set up at a distant point on the earth's surface can be found. Focusing and interference effects produce a high field, rapidly fluctuating with distance, just beyond the skip distance, and a high field at the limiting distance for the tangential ray.

621.396.81 : 551.510.535 1230

'M-Mode' Propagation Possibilities.—D. Lepechinsky. (*Nature, Lond.*, 25th Feb. 1950, Vol. 165, No. 4191, p. 307.) The ionization density of the E layer being greatest at the subsolar point, a two-hop ray passing near this point may be unable to penetrate the E layer to reach the ground, and be reflected instead back to the F layer, with resulting lower absorption. Outstandingly good reception has been observed on frequencies of 19 Mc/s and 14 Mc/s when this type of propagation had been predicted.

621.396.81.029.45 1231

Round-the-World Signals at Very Low Frequency.—J. N. Brown. (*J. geophys. Res.*, Dec. 1949, Vol. 54, No. 4, pp. 367–374.) Pulses were radiated from an omni-directional aerial at Annapolis, Maryland, and were received on a vertical loop 50 miles away. Transmitter power was 350 kW and frequency 18 kc/s. In March 1949, the delay time was 0.137 3 sec, corresponding to about 55 hops between an ionosphere layer at a height of 65 km and the ground. During an ionospheric storm the time fell to 0.136 5 sec. The maximum attenuation of round-the-world signals is about 70 db; near local sunset it falls to a sharp minimum of about 56 db.

621.396.81.029.58 1232

Study of the Propagation of Decametre Waves by means of Standard-Frequency Transmissions.—B. Decaux, M. Barré & G. Bertaux. (*C. R. Acad. Sci., Paris*, 23rd Jan. 1950, Vol. 230, No. 4, pp. 378–380.) A résumé of the measurements of the frequencies and field strengths at Bagneux of the transmissions from Washington WWV and Hawaii WWVH. During breaks in the WWVH transmission, frequency stability of the WWV signal clearly improved. Permanent recordings were made at Bagneux of the 15- and 20-Mc/s carriers and of the 440-c/s modulation. Better reception of WWVH on 15 Mc/s, despite greater distance and lower power, was particularly evident in the early morning. Identical conclusions can be drawn from records obtained on the s.s. *Commandant Charcot* during her voyage between South Africa and Australia, especially in the late afternoon and at nightfall. Typical records are reproduced. See also 1227 above and 1725 of 1948 (Decaux).

621.396.812.3 : 551.510.535 1233

The Analysis of Observations on Spaced Receivers of the Fading of Radio Signals.—B. H. Briggs, G. J. Phillips & D. H. Shinn. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 106–121.) The fading of a radio wave once reflected from an irregular ionosphere is discussed in terms of the variable diffraction pattern produced at the ground. Fading may arise either from a drift of the pattern past a receiver, or from irregular time variations in the pattern, or both. Observations at three receiving points can be used to deduce the rate at which the pattern changes and the drift velocity with respect to the ground. For practical results see 96 of January (Mitra).

RECEPTION

621.396.621 1234

Denco Model DCR19 Communications Receiver.—(*Wireless World*, Feb. 1950, Vol. 56, No. 2, pp. 50–52.) Test report of a receiver with six overlapping ranges covering the band 175 kc/s–30 Mc/s. Special features include a crystal calibrator and a well-made rotary coil-turret which removes all idle coils from the circuit and short-circuits any that might act as absorbers for the coils in use. Circuit details are given of the interstage coupling following the first i.f. valve, and also of the first a.f. amplifier, which includes a negative-feedback circuit acting as a filter.

621.396.621 1235

Communication Receiver Design.—D. W. Heightman. (*R.S.G.B. Bull.*, Feb. 1950, Vol. 25, No. 8, pp. 253–258.) Technical and economic factors governing the efforts of the set designer and manufacturer to meet the requirements of the average buyer and operator are reviewed. Only a.m. telephony and telegraphy reception in the range 150 kc/s to 35 Mc/s is considered. Emphasis is on amateur requirements. The design of r.f., mixer and i.f. stages is discussed and certain refinements are recommended.

621.396.621 : 621.385 1236

A Gated Beam Tube.—Adler. (*See* 1292.)

621.396.621.22 1237

Marine Communal Aerials.—(*Wireless World*, Feb. 1950, Vol. 56, No. 2, pp. 73–74.) Description of two systems providing interference-free reception on a large number of receivers. Filter circuits in the communal aerial reject the interference due to the ship's transmitters, and in one system feed three basic output stages, which in turn may feed other supplementary units whose number depends on the size of the ship. In the second system the filtered output from the communal aerial is fed via a cathode follower to two wide-band amplifiers, one covering the medium- and long-wave bands and the other the short-wave broadcasting bands. The output from each chain is then distributed, after further amplification, by low-impedance lines throughout the ship.

621.396.664 1238

An Aerial Comparator and Monitor Unit.—J. D. Storer & S. Southgate. (*J. Brit. Instn Radio Engrs*, Jan. 1950, Vol. 10, No. 1, pp. 4–9.) An improved system for aerial selection and signal monitoring at receiving centres. Any available aerial may be applied, via a coaxial switch, to a monitor receiver the i.f. output of which is displayed on the screen of a c.r. tube. Any two aerials may be switched alternately to the monitor receiver, either manually or at high speed by electronic means, to obtain a visual comparison on the c.r. tube, the timebase being locked to the aerial switching speed.

621.396.822 1239

On the Spectral Distribution of Energy of Voltage Fluctuations at the Output of a Radio-Noise Receiver.—J. Mosnier & J. L. Steinberg. (*C. R. Acad. Sci., Paris*, 30th Jan. 1950, Vol. 230, No. 5, pp. 438–440.) Three conclusions are drawn from the results of experiments in which the noise spectrum of a receiver was compared with the uniform spectrum of current fluctuations of a saturated diode: (*a*) there exists in the receiver itself a hitherto unnoticed source of fluctuations which must be looked for in the valves themselves; (*b*) the spectrum of these fluctuations has a hyperbolic trend and the amplitude becomes negligible with respect to normal fluctuations only towards 500 c/s; (*c*) a system of periodic commutation at a.f. proposed by Dicke [475 of 1947] must be operated at above 500 c/s to eliminate these parasitic fluctuations.

621.396.828 1240

Radio Interference: The Work of the E.R.A. on Suppression of Interference from Electrical Equipment.—(*Brama J.*, Dec. 1949, Vol. 56, No. 150, pp. 412–413.) Brief outline of investigations of radio interference from domestic and industrial electrical equipment and from combustion engines. The relevant British Standards publications are listed.

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 1241

Theory of Communications.—P. Aigrain. (*Ann. Télécommun.*, Dec. 1949, Vol. 4, No. 12, pp. 406–411.) Statement of the recently developed theory of Shannon (1361 of 1949) showing the relations existing between the bandwidth of a communication channel, the type of signal transmitted, and the signal/noise ratios at the input and the output of the receiver used.

621.394.5 + 621.396.71 1242

The Italcable Radio-Receiving and Submarine-Cable Station at Acilia.—A. Niutta. (*Poste e Telecomunicazioni*, July 1949, Vol. 17, No. 7, pp. 373–386.) General description of a new station, some 24 km from Rome, to replace stations lost during the war. World-wide radio and cable links are provided. The space-diversity system is used for reception, the rhombic aerials simultaneously receiving signals from two opposite directions. To avoid interference, all cable equipment is enclosed in a Faraday cage.

621.395.44 : 621.315.052.63] : 621.395.658.076.7 1243

Voice-Operated Switching of Carrier Systems.—R. C. Fox, F. S. Beale & G. W. Symonds. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 92–95.) An all-electronic transfer unit provides two-way or party-line communication over power line or radio carrier systems using a single frequency. The equipment functions at a high speed and makes it possible for the speaker to be interrupted by the listener. Oscillograms show negligible speech clipping at the start.

621.395.5 : 621.315.212 1244

Coaxial-Cable Telephony Transmission Systems.—L. Albanese & P. Schiaffino. (*Poste e Telecomunicazioni*, March 1949, Vol. 17, No. 3, pp. 141–167.) A comprehensive survey covering problems of design peculiar to coaxial-cable telephony, and the solutions arrived at in current practice for cable dimensions, channel frequency allocation, transmitting equipment, supervisory gear and power supply. Line-amplifier problems, in particular interstage valve coupling, distortion, and output-impedance matching, are treated in some detail.

621.396.1 1245

The Provisional Frequency Board.—P. F. Siling. (*RCA Rev.*, Dec. 1949, Vol. 10, No. 4, pp. 600–607.) Short account of the functions of the Board as laid down at the Atlantic City conference, and of its work up to the present.

621.396.5 1246

Citizens Radio Ranger.—(*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 136, 138.) A short account of tests carried out by the Hallicrafters Company with experimental equipment operated from batteries. The transmitters used grid modulation of about 30% on peaks, and $\lambda/2$ folded dipoles served as aerials. The maximum ranges for two hand-held transceivers varied from 7 miles, both sets being 33 ft above ground level and intervening terrain flat and clear, to 0.2 miles with both sets at a height of 6 ft and intervening terrain entirely wooded. When one dipole aerial was replaced by a highly directional corner-reflector type of aerial, the maximum ranges were three times greater.

Using a mobile unit with a ground-plane aerial mounted on top of a car and another unit which fed 15-W r.f. power into a corner-reflector aerial mounted on top of a 75-ft tower, reasonable communication was possible at distances up to 3 miles in a typical residential section, and up to 9 miles in less-populated areas.

621.396.931 1247

V.H.F. Radio Equipment for Mobile Services.—D. H. Hughes. (*Radio tech. Dig., Edn franç.*, Dec. 1949, Vol. 3, No. 6, pp. 305–308 & Feb. 1950, Vol. 4, No. 1, pp. 43–49.) French version of 1797 of 1949, with added bibliography.

621.396.931 1248

Planning V.H.F. Mobile Systems.—E. R. Burroughes. (*Marconi Rev.*, Jan./March 1950, Vol. 13, No. 96, pp. 37–46.) Discussion of the advantages obtainable from a correctly planned v.h.f. system, and information on the type of equipment available for mobile services.

621.396.933 : 621-526 1249

Electrical Remote-Control and Indicating Systems in Airborne Radio Equipment.—Gamlen. (*See* 1254.)

621.396.97 : 654.191 1250

Economies in the Planning, Design and Operation of a Sound Broadcasting System.—R. T. B. Wynn. (*Proc. Instn elect. Engrs*, Part III, Jan. 1950, Vol. 97, No. 45, pp. 1–10. Summaries in *Proc. Instn elect. Engrs*, Part I, Jan. 1950, Vol. 97, No. 103, pp. 7–8 & *Engineer, Lond.*, 2nd Dec. 1949, Vol. 188, No. 4897, pp. 636–640.) Inaugural address as Chairman of the Radio Section of the I.E.E. The development of continuity working and programme input equipment in studio centres is considered. Automatic monitors designed by B.B.C. engineers are described and economies effected by the use of such monitors are discussed. The problem of economic balance between station installation and running costs and freedom from breakdown is considered; details are tabulated of capital costs (1943) for the construction of the Skelton s.w. transmitting station, and also comparative running costs of the Droitwich medium- and long-wave, Start Point medium-wave, and Skelton short-wave stations. Unattended transmitting stations are also discussed and the arrangements at present in use at various B.B.C. stations of this type for automatic frequency adjustment, routine checking and maintenance are outlined.

SUBSIDIARY APPARATUS

621-526 1251

Analysis of the Operation of Discontinuous Physical Systems and its Application to Servomechanisms.—F. H. Raymond. (*Ann. Télécommun.*, July–Oct. 1949, Vol. 4, Nos. 7–10, pp. 250–256, 307–314 & 347–357.)

621-526 1252

An Analysis of Relay Servomechanisms.—D. A. Kahn. (*Elect. Engng, N.Y.*, Feb. 1950, Vol. 69, No. 2, p. 155.) Summary of A.I.E.E. 1949 San Francisco Meeting paper. The differential equations governing a relay-controlled system are nonlinear and cannot be solved by conventional methods. Application of Laplace-transform

theory to such a system yields a response expressed in the form of a series from which the behaviour of the system may be determined. The method is applicable to any controlled system with a unilateral transfer function, such as a motor, valve circuit, or a complete servomechanism. Information concerning periodic oscillations and stability of such systems can be derived.

1253

621.526

Servomechanisms and Telecontrol.—Y. Rocard & J. Loeb. (*Ann. Télécommun.*, Nov. 1949, Vol. 4, No. 11, pp. 397–404.)

1254

621.526 : 621.396.933

Electrical Remote-Control and Indicating Systems in Airborne Radio Equipment.—D. R. Gamlen. (*Marconi Rev.*, Jan.–March 1950, Vol. 13, No. 96, pp. 1–20.) Remote-control systems for receivers, transmitters and radio compasses, which are small and adapted to conventional aircraft voltage supplies, are discussed. Devices used in these systems are described and include a controller switch drive, a preselector unit and a.c. and d.c. selsyns, both the self-synchronous and "Motaysynn" a.c. systems being treated.

1255

621.355.8

New Lightweight Accumulator.—C. L. Chapman. (*Elect. Rev., Lond.*, 24th Feb. 1950, Vol. 146, No. 3770, pp. 345–347.) A special method of construction, using Ag and Zn electrodes in KOH electrolyte, provides an unspillable, rechargeable battery of $\frac{1}{3}$ the size and $\frac{1}{4}$ the weight of the lead acid accumulator of equivalent capacity. It requires normal maintenance and its characteristics are similar to those of the Ni-Fe cell. Nominal voltage during discharge is 1.5 V. Types to be made available comprise 0.5, 1, 3, 5, 15, 20 and 40 A.hr units. A 1-A.hr cell only weighs 1 oz. Specifications of various types are tabulated. 40 W.hr/lb weight is a standard production achievement. When being charged, only minute quantities of hydrogen are evolved.

1256

621.396.68 : 621.397.5

Metal-Rectifier Voltage Multipliers for E.H.T. (extra-high-tension) **Supplies.**—A. H. B. Walker. (*J. Televis. Soc.*, Sept. 1949, Vol. 5, No. 11, pp. 311–317.) Discussion of the operating principles and characteristics of cascade voltage multipliers of the Cockcroft type, and description of a multiplier giving an output of 10 kV and operated from the 350–0–350-V secondary of a centre-tapped transformer. Pulse-operated multipliers are also considered briefly.

1257

621.396.682.027.5.6

Variable High-Voltage Power Source.—W. S. Ramsey. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 98–101.) Two separate units for the ranges 5–10 kV and 10–30 kV, with regulation better than 0.05%. In series they will give a current of 2 mA at 40 kV with <0.1% ripple voltage.

1258

621.398

Radio Synchro-Motor (selsyn).—J. Loeb, J. R. Duthil & A. Jeudon. (*Ann. Télécommun.*, March 1949, Vol. 4, No. 3, pp. 87–102.) A study of different transmission systems in which angular motion or intelligence is represented by phase modulation.

TELEVISION AND PHOTOTELEGRAPHY

1259

621.397.331

Improved Television Modulator.—J. Haughawout. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 86–88.) A circuit is described, with complete component details, which gives a constant synchronization signal and holds the output black level at a predetermined voltage. When this modulator is used, on switching from one programme source to another, the receiver picture fades out and does not return till the resynchronization process is completed. Provision is also made for emergency operation in case the keyed clamping circuit fails.

1260

621.397.331.2

A New Image Orthicon.—R. B. Janes, R. E. Johnson & R. R. Handel. (*RCA Rev.*, Dec. 1949, Vol. 10, No. 4, pp. 580–592.) "The design of a new panchromatic high-sensitivity photo-surface has resulted in the development of a new image orthicon, RCA-5820, which permits the televising of low-level illuminated scenes with a faithful gray-scale rendition of colors. Performance results of this new tube in comparison with other types for both remote and studio pickup are given."

1261

621.397.331.2

Some Considerations on a Scanning Tube for Film.—N. Schaetti. (*Le Vide, Paris*, Jan. 1950, Vol. 5, No. 25, pp. 739–747.) A general discussion of cathode coatings for photoelectric and electron multiplier tubes, and a description of a tube designed for 729-line scanning of cinematograph film. This operates on the principle of Farnsworth's image dissector, transmitting 25 frames per second. An Sb/Cs cathode is used. A 1-V signal is obtained, so that additional amplification is not required. Investigations are to be made with a concave cathode and with interlaced scanning.

1262

621.397.331.2

Manufacturing Metallized Picture Tubes.—E. R. Ewald. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 76–79.) Details of techniques by which the phosphor coating of a television picture-tube screen is covered by a film on which a thin coating of Al is evaporated, the film being removed by heat prior to the final evacuation.

1263

621.397.5

A Six-Mc/s Compatible High-Definition Color Television System.—R.C.A. Laboratories Division. (*RCA Rev.*, Dec. 1949, Vol. 10, No. 4, pp. 504–524.) Colour-picture sampling and time-multiplex transmission together with the "mixed-highs" principle enable the colour transmission to be compressed into a 4-Mc/s band suitable for a total channel assignment of 6 Mc/s. Each primary colour signal passes through a low-pass filter (0–2 Mc/s) and is then passed to an electronic commutator. The three-colour signals are also sent to a band-pass filter (2–4 Mc/s) the output being the "mixed-high" signal which is added to the signals from the commutator and then passed through a low-pass filter (0–4 Mc/s). Various receivers and colour converters are illustrated and described. The standard scanning speeds are used so that a monochrome picture can be received on existing receivers.

1264

621.397.5

Dot Systems of Color Television.—W. Boothroyd. (*Electronics*, Dec. 1949, Vol. 22, No. 12, pp. 88–92 & Jan. 1950, Vol. 23, No. 1, pp. 96–99.) Short accounts of several sequential sampling and multiplex methods that permit reception either in colour or monochrome with the appropriate receiver.

1265

621.397.5

Geometrical Study of the Optimum Number of Channels for Television.—Payen. (*Onde Elect.*, Nov. 1949, Vol. 29, No. 272, pp. 398–401.) Discussion of the problem of providing satisfactory service over extensive territory by means of a number of suitably located stations transmitting the same programme on selected frequencies.

1266

621.397.5 : 535.88

Stereoscopic Television.—F. Lachner. (*Radio Tech., Vienna*, Dec. 1949, Vol. 25, No. 12, pp. 699–701.) Different methods of stereoscopic viewing and projection are reviewed, particularly those requiring the viewer to wear special eye-pieces. The application of a special c.r. tube to stereoscopic colour television is described. This tube is divided into six chambers for left and right scanning in the three primary colours; a combination of prisms and reflectors is used for composition of the coloured image.

621.397.5 : 621.315.212 1267

Television Terminals for Coaxial Systems.—L. W. Morrison, Jr. (*Elect. Engng, N.Y.*, Feb. 1950, Vol. 69, No. 2, pp. 109–115.) By double modulation the L-1 coaxial-line terminal equipment transforms the video frequencies to frequencies 200 kc/s higher, which can be transmitted efficiently over the line (transmission band 64–3 100 kc/s). The original frequencies are restored in the receiver by a double demodulation process. Vestigial-sideband transmission is used. The equipment and its operation are described.

621.397.5 : 621.396.68 1268

Metal-Rectifier Voltage Multipliers for E.H.T. [extra-high-tension] **Supplies.**—Walker. (*See* 1256.)

621.397.5 : 621.396.813 1269

Artificial Lines for Video Distribution and Delay.—A. H. Turner. (*RCA Rev.*, Dec. 1949, Vol. 10, No. 4, pp. 477–489.) Delay distortion may be reduced by the use of mutual inductance between adjacent half-sections of a low-pass filter. A combination of such T sections and bridged-T sections gives small delay distortion up to 0.85 of the cut-off frequency. The quality of picture signals transmitted through several experimental lines of 20 sections each confirmed this theory. Each section provides a low-impedance feed point and the branch lines from these points must behave as lumped capacitors; they must therefore be unterminated and short compared with the signal wavelength. Input and output voltages are sketched for various values of mutual coupling. The work of other investigators is briefly reviewed and 14 relevant publications are noted.

621.397.61 1270

Low-Power Television Transmitter.—L. Voorhees. (*Elect. Engng, N.Y.*, Feb. 1950, Vol. 69, No. 2, pp. 151–154.) Description, with block diagrams, of equipment designed for local coverage. The sound transmitter has an output of 250 W; that of the video transmitter is 500 W. Separate transmitters are used for the low and the high television-frequency bands.

621.397.62 1271

The Simplification of Television Receivers.—W. B. Whalley. (*Sylvania Technologist*, Jan. 1950, Vol. 3, No. 1, pp. 9–12.) An investigation of general means of simplifying television receivers so as to reduce the costs of production and servicing. The operation of a television receiver is analysed from the standpoint of the minimum number of necessary functions, and then the simplest possible circuit to perform each function is planned, taking into consideration the possibility of combining two functions in the same circuit.

621.397.62 1272

Fixed-Tuned Broad-Band Television Booster.—A. Newton. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 116 . . 134.) The booster is intended to improve the overall noise figure and raise the useful gain of a receiver. The first r.f. stage, a grounded-grid triode amplifier, is coupled to the second stage by a double-tuned inductively coupled circuit, the output of which is fed to the receiver through a 300-Ω input resistance. Separate high-band and low-band amplifiers are used and the respective inputs and outputs are connected through a crossover network consisting of $\lambda/4$ sections. Total gain is about 8.

621.397.62 : 621.396.67 1273

Trends in TV Receiver Antenna Design.—Kamen. (*See* 1085.)

621.397.62.001.4 1274

Measurement of Transient Response of TV Receivers.—Van Duyne. (*See* 1194.)

621.397.62.029.63 : 621.385.2 : 621.315.59 1275

Germanium Diodes for U.H.F. TV.—Lingel. (*See* 1307.)

621.397.822 1276

Perception of Television Random Noise.—P. Mertz. (*J. Soc. Mot. Pict. Television Engrs*, Jan. 1950, Vol. 54, No. 1, pp. 8–34.) The problem is studied by analogy with graininess in a photographic image. Effective random noise power is obtained by cumulating and weighting actual noise powers over the video frequencies with a weighting function diminishing with increasing frequency. Values obtained check reasonably well with preliminary experiments. The effect of changing the tone rendering and contrast of the television image is analysed.

621.397.828 1277

Television Interference seldom comes from Power Systems.—F. L. Greene. (*Elect. World, N.Y.*, 16th Jan. 1950, Vol. 133, No. 3, pp. 55–59 . . 128.) The principal causes of interference with television reception so far encountered are listed and their effects on the television screen illustrated. Methods of eliminating the interference are suggested. Ignition systems cause most interference; domestic and industrial apparatus are less troublesome. Interference from power lines is slight.

621.397.828 1278

Some Devices for Reducing the Effects of Fading and Interference: Part 1.—D. McMullan. (*J. Televis. Soc.*, Sept. 1949, Vol. 5, No. 11, pp. 318–328.) The various types of interference encountered in the reception of television signals are reviewed and methods of reducing such interference are discussed, with special reference to circuit techniques which may be used in the design of the receiver. Future problems are considered, and the respective merits of positive and negative modulation are discussed from the point of view of their susceptibility to interference.

621.397.828 1279

Suppression of TVI.—F. T. Wilson. (*Short Wave Mag.*, Dec. 1949 & Jan. 1950, Vol. 7, Nos. 10 & 11, pp. 740–745 & 828–832.) A detailed account of an investigation of the source of television interference in an amateur transmitter and of its elimination by means of low-pass filters, effective screening and suitable modification of the power amplifier. A circuit diagram, with component values, is given of a push-pull amplifier including harmonic-suppression arrangements. Final tests of the modified transmitter when radiating 100 W on a frequency of 14 Mc/s showed only a trace of interference with a television receiver only 2 ft away from the transmitter.

Reception tests on local amateur stations, with the receiver tuned to frequencies of the order of 42–43 Mc/s, showed that the strongest harmonics were received from transmitters using single-ended output stages with beam tetrodes, while transmitters using variable-frequency oscillators had very weak harmonics.

TRANSMISSION

621.316.726 1280

Carrier Frequency Control: Automatic System for Unattended Transmitting Stations.—J. C. Gallagher. (*B.B.C. Quart.*, Winter 1949/50, Vol. 4, No. 4, pp. 249–256.) The Droitwich standard-frequency transmission of 200 kc/s is used to effect the near synchronization of unattended transmitters. Frequency dividers and pulse-shaping circuits are used to generate a train of 0.6-μs pulses with a recurrence frequency of 1 000 per sec, which are fed together with the locally generated carrier into two integrating circuits; from these pulses are derived, each corresponding to a frequency change of ± 2 parts in 10^8. The pulses drive an impulse motor coupled to a series capacitor in the crystal-oscillator circuit.

621.396 : 621.394.611.2 1281

An Electronic Keyer.—B. Bröndum-Nielsen. (*R.S.G.B. Bull.*, Feb. 1950, Vol. 25, No. 8, pp. 259–260, 262.) Description of an easily constructed semi-automatic keying unit. Dash/dot and mark/space ratios can be adjusted to be correct for any sending speed within the range of the unit. The resulting Morse signals compare favourably with those of an automatic tape transmitter.

621.396.61 1282

Aircraft Communications Transmitter Type AD.107.—W. R. Bitcheno. (*Marconi Rev.*, Jan./March 1950, Vol. 13, No. 96, pp. 21–36.) Transmitters are described for h.f. and m.f., each comprising four units: driver and modulator, amplifier, aerial and power units. The h.f. transmitter, weighing 85 lb, with a maximum power of 150 W, operates on 10 crystal-controlled spot frequencies in the range 2–18.5 Mc/s. The 80-lb m.f. transmitter, with maximum output of 120 W in the range 320 to 520 kc/s, has identical controls and the same number of crystal-controlled frequencies as the h.f. equipment.

621.396.61 1283

Band-Switch QRO Transmitter.—J. S. Walker. (*Short Wave Mag.*, Jan. 1950, Vol. 7, No. 11, pp. 818–827.) Full circuit and construction details of a 3-stage transmitter for full-power operation in the range 3.5–28 Mc/s. Switched coil turrets are used for both driver and power-amplifier. Only a keyed v.f.o. is needed for c.w. working. The set is adaptable for either screen or anode-and-screen modulation of the power amplifier for telephony. Standard British components are used throughout.

621.396.615 1284

3-kW M.F. Transmitter Design.—I. F. Deise & L. W. Gregory. (*Communications*, Oct.–Dec. 1949, Vol. 29, Nos. 10–12, pp. 12–14, 33, 12–13 & 30–31.) In order to reduce the size of the transmitter, h.f. iron-cored transformers are used; the construction and the operational characteristics of these are described. The cores are of hipersil iron. An autotransformer with 5% tappings is used for matching the reflected aerial impedance to that of the power amplifier. The working frequency can be anywhere in the range 250–540 kc/s and arrangements are provided for immediate switching, when desired, to a second frequency in the same range.

621.396.619.13 1285

Square-Wave Keying of Oscillators.—J. C. Seddon. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 102 , . 172.) A low-power circuit is described which makes possible square-wave grid-modulation of oscillators over a wide range of pulse widths and duty cycles. 750-V positive pulses can be produced from 15-V negative pulses with a maximum current of 15 mA, the rise and decay times being $< 1\ \mu s$. 15-W average power will easily control an oscillator giving 7.5 kW peak power output.

VALVES AND THERMIONICS

537.122 : 531.112 : 537.525.92 1286

Electron Transit Time in Space-Charge-Limited Current between Coaxial Cylinders.—P. L. Copeland & D. N. Eggenberger. (*J. appl. Phys.*, Dec. 1949, Vol. 20, No. 12, pp. 1148–1151.) The transit time of electrons between a cylindrical cathode and an external concentric anode can be determined if the potential distribution between the cylinders is known. Taylor series expansions are developed for this in a form which enables the transit times to be readily calculated to within 0.1%.

537.58 : 539.234 1287

Thermionic Emission of Thin Films of Alkaline Earth Oxide Deposited by Evaporation.—Moore & Allison. (*See* 1165.)

621.383 1288

Design Features of a New Photocell.—J. H. Crow & V. C. Rideout. (*Radio & Televis. News, Radio-Electronic Engng Supplement*, Feb. 1950, Vol. 14, No. 2, pp. 8–9, 28.) The photocell Type CE-70V is a high-vacuum, end-on type of tube, with two ring anodes and a flat disk-type cathode, which may be used as a combination modulator and photocell at carrier frequencies up to at least 200 kc/s. The inner ring is the control anode and serves to vary the emission current reaching the load anode. Light striking the cathode controls the emission. Its application in an electro-optical pyrometer is described, where the comparison of the light intensities at two wavelengths is used to determine the absolute temperature of a luminous flame.

621.385 1289

New Valves.—J. Steiger. (*Bull. schweiz. elektrotech. Ver.*, 18th Feb. 1950, Vol. 41, No. 4, pp. 112–121. In French.) An illustrated review of the most recent thermionic valves, camera tubes, magnetrons, memory tubes, electron multipliers, electron couplers, and of the "selectron" developed in the R.C.A. laboratories.

621.385 1290

New Subminiature Valves.—C. C. Gee. (*Wireless World*, Feb. 1950, Vol. 56, No. 2, pp. 46–47.) These are flat types with filament currents of only 15 mA. Performance is comparable with that of the corresponding Mullard 10-mm valves (2410 of 1948), but anode and filament currents are both much lower and the reduced size and flat shape results in a saving of space of about one-third compared with the 10-mm valves, when three valves are fitted in a hearing aid. The 10-mm range is also being extended for both mains and battery operation, for use in miniature equipment.

621.385 : 621.396.621 1291

A Survey of Modern Radio Valves: Part 3 — Receiving Valves for Use below 30 Mc/s.—K. D. Bomford. (*P.O. elect. Engrs' J.*, Jan. 1950, Vol. 42, Part 4, pp. 201–208.) The modes of operation of the more widely used types of receiving valve are discussed and contrasted and the various factors limiting their performance are considered. Data are included on the physical form and the characteristics of modern valves, and the operating conditions conducive to long life are discussed. Parts 1 and 2: 482 and 483 of February.

621.385 : 621.396.621 1292

A Gated Beam Tube.—R. Adler. (*Electronics*, Feb. 1950, Vol. 23, No. 2, pp. 82–85.) This valve, Type 6BN6, uses a sharply-focused electron beam passing through two control grids, each of which has an unusually steep and linear transfer characteristic. It is suitable for use in f.m. discriminator circuits, as a synchronization-pulse separator, or as a square-wave generator. The assembly fits into a miniature-valve envelope with a 7-pin base.

621.385 : 621.396.621 1293

Contour Analysis of Mixer Valves.—N. E. Goddard. (*Wireless Engr*, Nov. 1949, Vol. 26, No. 314, pp. 350–356.) "The characteristics of a mixer valve are completely defined by a series of three-dimensional surfaces. Two of the coordinates, grid voltage and heterodyne-oscillator voltage, determine the operating conditions for small signal voltages. The third coordinate is one of a number of valve parameters: fundamental or harmonic conversion conductance, cathode current or grid current. Each surface is described by a contour map on which load lines are drawn for several automatic-bias circuits. The method is illustrated by Fourier analysis of a theoretical mutual-conductance curve and by experimental measurements on an EF42 pentode."

621.385.029.63/.64 + 621.396.615.14 1294

The Amplification of Centimetre Waves: Travelling-Wave Valves.—G. Goudet. (*Onde élect.*, Jan. 1950, Vol. 29, No. 274, pp. 8–12.) Some typical performance figures are given for klystrons and triodes at 3 000 Mc/s and the development of the travelling-wave valve in different laboratories is reviewed. Details are given of the design and construction of the valves produced in the Laboratoire Central de Télécommunications. Their mean operating frequency is 2 600 Mc/s; pass band, 400 Mc/s; output power, 30 mW; noise factor, 18 db; gain, 35 db for a useful current of 3 mA. The bibliography includes 42 references.

621.385.029.63/.64 + 621.396.615.14 1295

Valves for Communication on Frequencies above 1 000 Mc/s: Part 2.—H. Schnitger. (*Fernmeldetech. Z.*, Jan. 1950, Vol. 3, No. 1, pp. 13–22.) An illustrated description and comparison of three types of microwave amplifiers: (*a*) the disk-seal triode; (*b*) the klystron; (*c*) the travelling-wave valve. The disk-seal triode is very useful for wavelengths near 10 cm, where its noise factor is about 8, rising to about 60 for 3-cm wavelength. The noise factor of the travelling-wave valve is appreciably higher and the klystron has both higher noise factor and relatively small bandwidth. Part 1: 2105 of 1949.

621.385.029.63/.64 1296

The Traveling-Wave Tube (Discussion of Waves for Large Amplitudes).—L. Brillouin. (*J. appl. Phys.*, Dec. 1949, Vol. 20, No. 12, pp. 1196–1206.) Equations are developed for the interaction of an electron beam with an e.m. wave in a simplified linear model with infinitely short sections. Hence the usual theory for waves of small amplitude, assuming a strong beam with a weak signal, is derived and the precise limits of the validity of this theory are defined. For waves of large amplitude, the amplified wave is progressively distorted until a final stage is reached, dependent essentially upon the details of the tube structure, when no further amplification is possible. In some cases, a type of shock wave results, with a complete bunching of the space charge. A similar solution applies also to linear accelerators and to synchrotrons.

621.385.029.63/.64 1297

Travelling-Wave Valve T.P.O.85.—(*Ann. Radioélect.*, Jan. 1950, Vol. 5, No. 19, pp. 62–63.) A linear amplifier valve made by the Compagnie Générale de T.S.F. for operation between 1 500 and 5 000 Mc/s. Max. output power, 1 W; gain, 15–19 db; pass band, 80–100 Mc/s; total length, about 460 mm, max. diameter, about 41 mm.

621.385.029.63/.64 1298

Recent Developments in Traveling-Wave Tubes.—L. M. Field. (*Electronics*, Jan. 1950, Vol. 23, No. 1, pp. 100–104.)

621.385.029.63/.64 : 621.396.822 1299

Transit-Time Effects in U.H.F. Valves.—A. H. Beck; J. Thomson. (*Wireless Engr*, Nov. 1949, Vol. 26, No. 314, pp. 379–380.) Comment on 3312 of 1949 (Thomson) and Thomson's reply.

621.385.032.213 1300

Activation Phenomena with Thoria Cathodes.—O. A. Weinreich. (*J. appl. Phys.*, Dec. 1949, Vol. 20, No. 12, p. 1256.) An investigation has been carried out into the activation of thoria-coated tungsten cathodes by (*a*) reverse electron current, (*b*) exposure to evaporation products from a nearby operating thoria cathode. The highest emission at temperatures at which thermal activation is negligible is given by the reverse electron current method. In some cases the emission passes through a maximum when plotted against the time during which reverse electron current is drawn. Procedure (*b*) was used for the activation of a pulsed thoria cathode, from which high emission could be maintained if a small d.c. emission was drawn from an auxiliary thoria cathode to the common anode.

621.385.032.213.2 : 621.317.336.1 1301

Change of Mutual Conductance with Frequency.—W. Raudorf. (*Wireless Engr*, Oct. 1949, Vol. 26, No. 313, pp. 331–337.) This phenomenon occurs in receiving valves with indirectly-heated cathodes after operation for about 1 000 hours. It is "due to the deterioration, during operation, of the contact between the oxide coating and the metal sleeve which forms the core of the cathode. It can be greatly reduced by giving the metal sleeve an appropriate shape. By applying Holm's theory of electric contacts it is possible to estimate the number and size of the contact spots (*a*-spots) between coating and core metal. For an average size of 3 μ for the oxide grain, for instance, and a contact resistance of about 40 Ω per cm^2 of the cathode surface, the number of *a*-spots is about 3×10^4 per cm^2 and their average diameter about 1 μ. The contact resistance and the liability to cathode sparking seem to be connected. In general, cathode sparking is unlikely up to a specific emission of 1 A/cm^2. To prevent sparking at pulse currents of 10 A/cm^2 of < 1-ms duration, the contact resistance between coating and core must be < 10 Ω/cm^2."

621.385.032.216 1302

Distribution of Potential in the Coating of an Oxide Cathode during a Pulse of Great Current Density.—R. Loosjes & H. J. Vink. (*Le Vide, Paris*, Jan. 1950, Vol. 5, No. 25, pp. 731–738.) The distribution was investigated by applying the method previously described (2414 of 1948) to specially constructed diodes having up to 3 metal probes inserted in the cathode coating. No barrier layer at the metal/oxide interface was found, but it was established that a great part of the potential drop occurs close to the emitting surface.

621.385.032.216 1303

Comparison between the Electronic and the Thermodynamic Temperature of Oxide Cathodes.—R. Champeix. (*C. R. Acad. Sci., Paris*, 2nd Jan. 1950, Vol. 230, No. 1, pp. 64–65.) From results of experimental tests on some ten valves whose thermodynamic temperature θ was varied between 850° and 1 200° K, the following conclusions are drawn: (*a*) the electronic temperature T is from 2% to 40% greater than θ; (*b*) the difference decreases with increasing temperature; (*c*) the difference is about halved if a plate electrode is used instead of a grid; (*d*) within the above temperature range $T \approx a\theta + b$, where $a < 1$. A theoretical explanation of the results will be given later.

621.385.032.216 : 537.583 1304

Thermionic Emission from Oxide Cathodes: Retarding and Accelerating Fields.—C. S. Hung. (*J. appl. Phys.*, Jan. 1950, Vol. 21, No. 1, pp. 37–44.) The effects of applied fields ranging from retarding fields up to accelerating fields of 50 kV/cm were studied. For strong retarding fields, excellent agreement with theory was obtained. Near zero field, cathode inhomogeneity or patch effect may be responsible for the deviations found; with the large cathode used, the existence or non-existence of a reflection effect could not be determined. For accelerating fields, deviations of the results from those predicted by the Schottky mirror-image theory are explainable by patch effect and by field intensification at sharp points of the rough cathode surface.

621.385.2 : 621.315.59 1305

Backward Current of Germanium Diodes.—P. Aigrain. (*C. R. Acad. Sci., Paris*, 2nd Jan. 1950, Vol. 230, No. 1, pp. 62–63.) Theory is given which leads to values of backward current in agreement with experimental values.

621.385.2 : 621.315.59 1306

Backward Current and Capacitance of Germanium Diodes.—P. Aigrain. (*C. R. Acad. Sci., Paris*, 9th Jan. 1950, Vol. 230, No. 2, pp. 194–196.) An experimental verification of the theory (see 1305 above) for the extreme cases of low and high back resistance, represented respectively by a transistor with the emitter disconnected and a Type-1N54 diode. Calculated and observed values of current for different voltages are tabulated. The calculated l.f. shunt capacitance for the transistor is 0.46 pF at 10 V; for the Type-1N54 diode, 0.1 pF.

621.385.2 : 621.315.59 : 621.397.62.029.63 1307

Germanium Diodes for U.H.F. TV.—F. J. Lingel. (*TV Engng, N.Y.*, Jan. 1950, Vol. 1, No. 1, pp. 12–13, 39.) The construction and application of mixer diodes for frequency conversion in the 475–890-Mc/s television band. The diodes can withstand microsecond pulses of 500 mA in the forward direction and 1 mA in the backward direction. The contact point is welded to the Ge pellet.

621.385.2 : 621.396.822 1308

Valve Noise and Electron Transit Time.—D. A. Bell. (*Wireless Engr*, Nov. 1949, Vol. 26, No. 314, p. 379.) Comment on 2097 of 1949 (Fraser).

621.385.2/.3.029.64 1309

Electronic Admittances of Parallel-Plane Electron Tubes at 4 000 Mc/s.—S. D. Robertson. (*Bell Syst. tech. J.*, Oct. 1949, Vol. 28, No. 4, pp. 619–646.) The general features of the mechanism of electron transit in close-spaced diodes are briefly reviewed. Measurements were made of the electronic admittance of close-spaced parallel-plane diodes and BTL1553 triodes (2964 of 1949) at 4 060 Mc/s, r.f. power being fed to the valve from a waveguide source through a waveguide-cavity transformer. The theory and practice of the method are described in detail. The diode conductance is found to be much greater than the l.f. value, and increases with decreasing electrode spacing. The susceptance decreases with increasing current. For the triode, the input short-circuit admittance departs considerably from values predicted by single-velocity theory, but the transadmittance is only slightly lower than the l.f. value. See also 1315 below.

621.385.3 : 621.315.59 1310

Characteristics of Transistors.—P. Aigrain & C. Dugas. (*C. R. Acad. Sci., Paris*, 23rd Jan. 1950, Vol. 230, No. 4, pp. 377–378.)

621.385.3 : 621.315.59 1311

Physical Interpretation of Type-A Transistor Characteristics.—L. P. Hunter. (*Phys. Rev.*, 15th Feb. 1950, Vol. 77, No. 4, pp. 558–559.) The relative efficiencies of the processes taking place in a transistor are discussed. For saturation conditions it appears that the poor performance of some transistors is due to low hole-injection efficiency. Below saturation the emitter may remove some electrons from the crystal, or the collector voltage may be insufficient for all the holes to reach the collector; either effect would cause a reduction in efficiency.

621.385.3 : 621.315.59 1312

The Germanium Crystal Triode.—H. Heins. (*Sylvania Technologist*, Jan. 1950, Vol. 3, No. 1, pp. 13–18.) The electrical properties of semiconductors are briefly discussed. The construction and characteristics of the crystal triode are then described and a few typical circuits are shown.

621.385.3.011.4 1313

Interelectrode Capacitance of Valves.—E. E. Zepler. (*Wireless Engr*, Nov. 1949, Vol. 26, No. 314, pp. 378–379.) Further discussion. See 2101 (Zepler & Hekner), 2102 (Humphrey & James) and 2962 (Booth) of 1949.

621.385.3.029.63 1314

Two Triodes for Reception of Decimetric Waves.—K. Rodenhuis. (*Philips tech. Rev.*, Sept. 1949, Vol. 11, No. 3, pp. 79–89.) A description of two receiving valves for frequencies higher than 300 Mc/s: a triode, Type EC80, for amplifying and mixing at frequencies up to about 600 Mc/s, and an oscillator, Type EC81, with an upper frequency limit of about 1 500 Mc/s. The nine copper-plated pins sealed through the glass base have a very low h.f. resistance. In contrast to the disk-seal valves commonly used for u.h.f. operation, these valves are similar in appearance to conventional types and enable receivers to be built which are simple in construction and easy to operate.

621.385.3.029.64 1315

Passive Four-Pole Admittances of Microwave Triodes.—S. D. Robertson. (*Bell Syst. tech. J.*, Oct. 1949, Vol. 28, No. 4, pp. 647–655.) Measurements at 4 060 Mc/s for a wide range of cathode/grid and grid/anode spacings are described. Two grids were used: (*a*) a parallel-wire grid of 0.3-mil tungsten wire wound at 1 000 turns/inch; (*b*) a criss-cross grid of the same wire wound at 550 turns/inch. The microwave transadmittances were found to be much higher than the values measured at l.f. See also 1309 above.

MISCELLANEOUS

43-3 = 2 1316

Technisches Wörterbuch (Deutsch-Englisch): Vol. 1. [Book Review]—R. Ernst. Publishers: Tauchnitz Edition, Hamburg, 612 pp., 16.50 DM. (*Elektrotechnik, Berlin*, May 1949, Vol. 3, No. 5, p. ir.) "The problem of including as many technical words as possible in a handy volume has been solved surprisingly well. Space economies in the case of related words and those common to the two languages might have been extended to include other less familiar equivalents, such as geschwindigkeitsmodulierte Röhre—klystron. More verbs are included than is usual in most technical dictionaries, and also the principal expressions for mathematical operations."

45-3 = 2 : 621.396 1317

Dizionario Tecnico della Radio. Italiano-Inglese. Inglese-Italiano. [Book Review]—L. Bassetti. Publishers: Il Rostro, Milan, 275 pp., 900 lire. (*Radio, Turin*, Nov. 1949, No. 8, pp. 5–6.) Radio terms and terms in physics and electronics connected with radio are explained. A list of abbreviations and symbols for circuit diagrams is included.

621.396 1318

Radio Engineering: Vol. 2. [Book Review]—E. K. Sandeman. Publishers: Chapman & Hall, Ltd, London, 579 pp., 40s. (*Wireless Engr*, Dec. 1949, Vol. 26, No. 315, pp. 412–413; *Wireless World*, Jan. 1950, Vol. 56, No. 1, p. 10.) The subject matter of this second half of the work includes interference and noise, receivers, measuring equipment, equalizer design, feedback, network theory, and filters. Appendices contain a large collection of formulae and information on a variety of subjects. Vol. 1 was noted in 600 of 1949.

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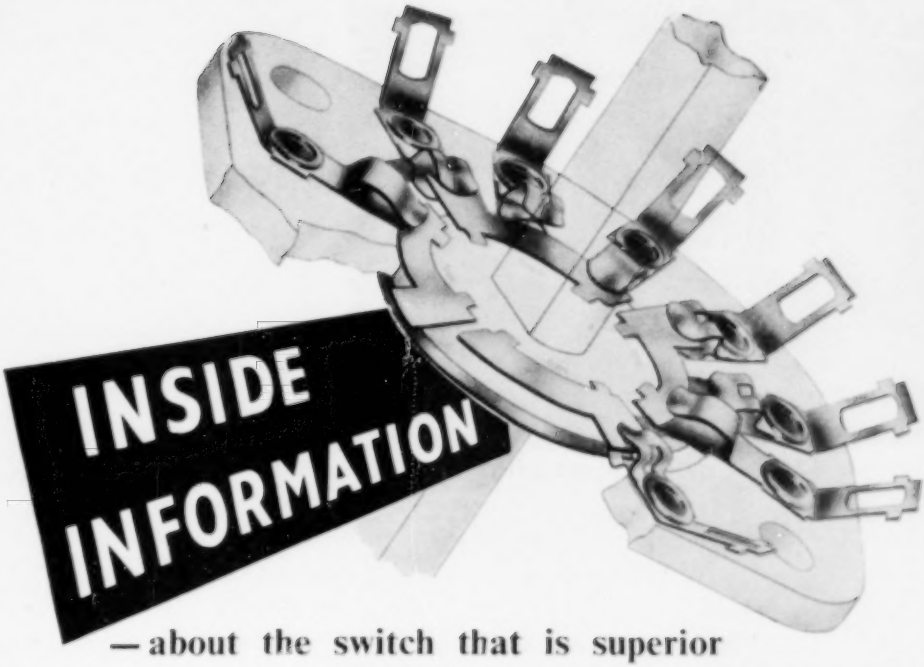

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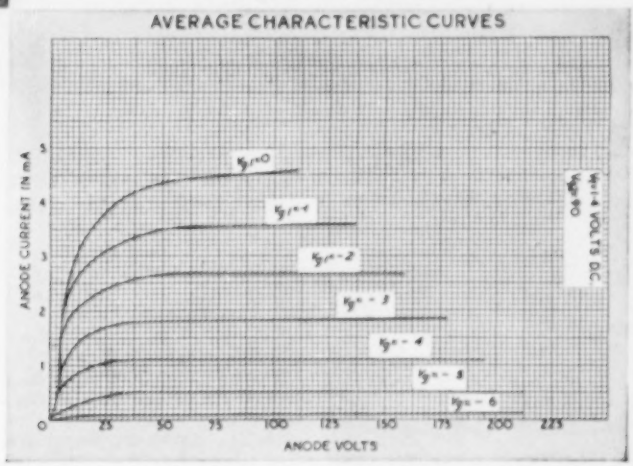

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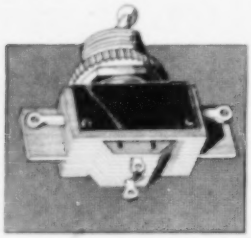

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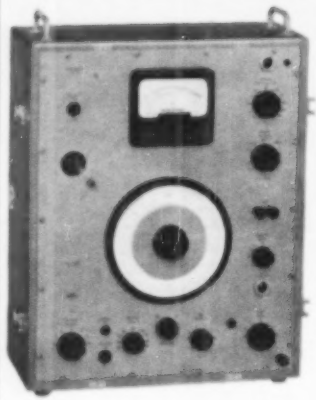

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In connection with the High-Speed Level Recorder Type 2301 this oscillator is particularly suitable for the recording of frequency-response characteristics of amplifiers, transmission lines, filters, loudspeakers and microphones, and in acoustical research for the automatic recording of sound insulation of walls, windows, doors, etc. and for the measurement of reverberation times. The accurate calibration of the attenuator and the valve voltmeter makes it eminently suitable for many other purposes. For acoustical work the oscillator is equipped with warble tone with variable modulation frequency and bandwidth. A special compressor makes it possible with an exterior voltage to regulate the output of the oscillator, which means, that it is possible to keep a constant sound pressure, electrical voltage or current.

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Frequency Range: 0–20,000 c/s. The scale is in accordance with C.C.I. standards and is illuminated and provided with an exclusive vernier drive. Connected to the Level Recorder 2301 the frequency will sweep from 0 to 20,000 c/s in 1.5 minutes.

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Compressor: The regulating amplifier controls a level range of about 45 db and maintains a constant sound pressure, electrical voltage or current. The regulating speed is about 300 db/sec.

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Dimensions: 20 (height) × 16 (width) × 8 (depth excl. dials) inches.

Manufactured by:

Brüel & Kjær

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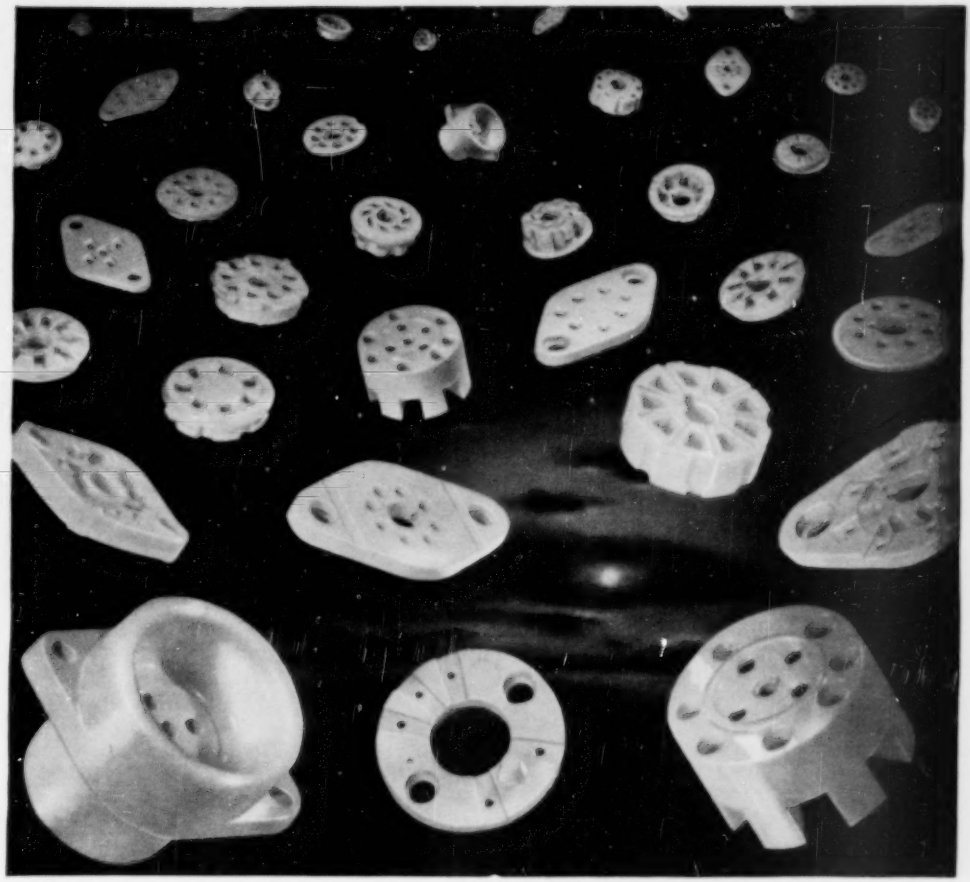
Further information on request



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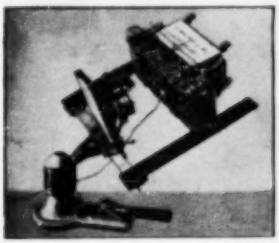

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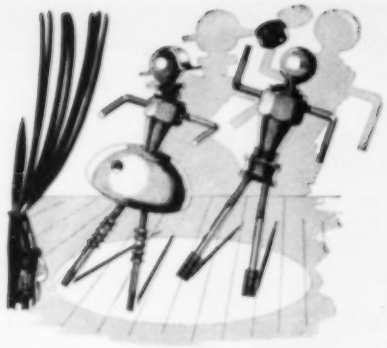

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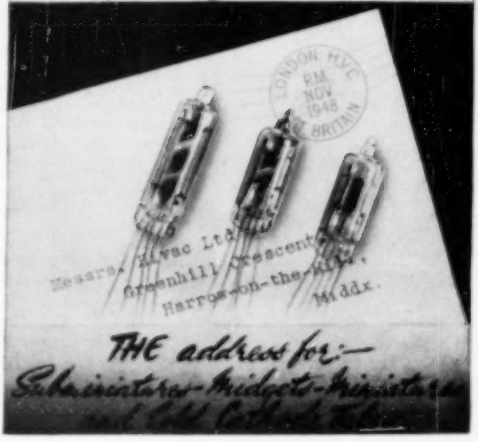

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A comprehensive instrument built into one compact and convenient case, which will test any standard receiving or small power transmitting valve on any of its normal characteristics under conditions corresponding to any desired set of D.C. electrode voltages. A patented method enables A.C. voltages of suitable magnitude to be used throughout the Tester, thus eliminating the regulation troubles associated with existing simple D.C. testing methods.

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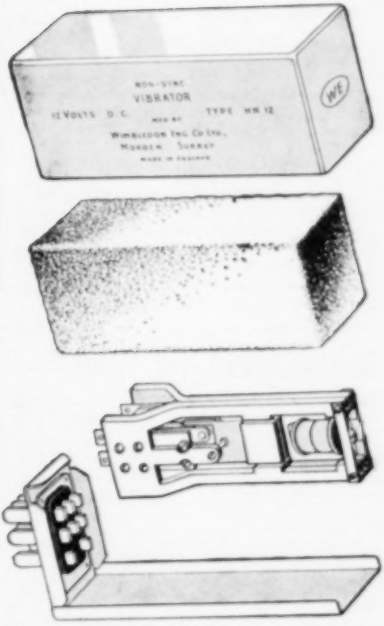

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GRC 4

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Applications are invited for permanent appointment to the Commonwealth Public Service as follows :—

Engineer, Grade 1—£A565–£A730

Engineer, Grade 2—£A730–£A775

Group Engineer £A775–£A865

The commencing salary will be determined according to qualifications and experience and paid from the date of embarkation for Australia.

Duties : Electrical, Mechanical or Civil Engineering as applied to Telephone, Telegraph, Radio and Broadcasting, Workshops and Production, Transport or Research Branches of Telecommunication Engineering, including design, construction and maintenance of associated internal and external plant and equipment.

Qualifications : Applicants must be born or naturalised British subjects and aged not more than fifty years and six months.

Minimum professional qualifications are :—

(a) A University Degree in Engineering (Four years' course) or

(b) A University Degree in Science (Three years' course) in subjects appropriate to engineering, supplemented by at least two years' suitable professional engineering experience ; or

(c) An approved Technical College Diploma in Engineering and at least three years' suitable professional engineering experience ; or

(d) The qualifications necessary for corporate membership in the Institutions of Electrical, Mechanical, or Civil Engineers of Great Britain or the Institution of Engineers, Australia, including suitable professional Engineering experience ; or

(e) Suitable experience as Assistant (or higher grade) Engineer of the British Post Office.

For appointment to positions above Grade 1, substantial professional experience is essential.

Prospects of advancement are good and rate of progress depends on individual capacity. The next highest engineering grade above Group Engineer is Divisional Engineer, the salary range of which is £A948–£A1,038.

Fares : Full first-class fares by ship to Australia of appointees and dependents will be paid by the Postmaster-General's Department subject to appointees entering into an undertaking to remain in the employ of the Commonwealth for a period of three years after arrival in Australia. It may not be practicable, however, for dependents to accompany appointees to Australia at the time of appointment.

Accommodation : If necessary, accommodation in Australia will be arranged initially.

Applications : To the Australian Post Office Representative, Australia House, The Strand, London, W.C.2.

Envelopes should be endorsed "Application for position of Telecommunication Engineer."

Applicants should state full names, date, year and place of birth, and whether they are natural born or naturalised British subjects. Education and experience should be stated in detail (preferably chronologically).

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The Governing Body invite applications for the post of Senior Assistant for Telecommunications. The Senior Assistant will be responsible for teaching Telecommunications and Electronics to the level of the B.Sc. (Eng.) degree of the University of London, and he will be expected to carry out and supervise research work in these subjects.

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Full particulars of the post and application forms may be obtained from the Clerk to the Governors to whom they should be returned within three weeks from the date of this advertisement.

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(a) engineering drafting, including design and detailing of electro-mechanical, mechanical or structural work ; or

(b) architectural drafting, buildings development and layout; or

(c) drafting work for telecommunication equipment installation and maintenance including layout, trunking, cabling and circuits.

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Applications : To the Australian Post Office Representative, Australia House, The Strand, London, W.C.2, stating full name, date, year and place of birth ; if natural born or naturalised British subject ; and full details education and experience (preferably chronologically).

Envelopes to be endorsed "Application for position of Engineering Draftsman."

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(b) Have passed or been exempted from Sections A and B of the Association Membership examination of the Institution of Mechanical or Electrical Engineers coupled with 2½ years practical workshop experience as an engineering apprentice.

Application Forms together with details of Pay, Allowances and Pension can be obtained from the War Office (MS.2(c)) London, S.W.1.

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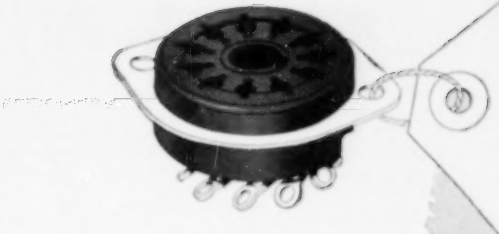

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Senior Electronic Development Engineer fully experienced in light Electro Mechanical Engineering required for development work in microwave transmission systems including the design of wave guide rotating joints, paraboloid reflectors with dipole feed and equipment for the measurement of antenna system polar diagrams. Box 3635 c/o. "Wireless Engineer."

Senior Electronic Engineer fully experienced in light Electro Mechanical Engineering required for development work in Industrial Electro Mechanical equipment. A thorough knowledge of general electrical engineering and electronic techniques is required. Applicants should be capable of carrying through a project to the production prototype entirely on their own initiative. Box 3636 c/o. "Wireless Engineer."

Assistant Radio Engineer required by Persian Gulf Oil Company for overseas service. Must be G.M.I.E.E. by Exam. in Radio Communication Engineering. Must have recent factory development experience in radio receiver production, and V.H.F. modulated receivers and transmitters. Also experience in design and maintenance of medium power W/T and R/T transmitters required. Free messing and accommodation. Tax free salary, starting £710 p.a. Write giving brief details age and experience quoting K.1094 to BOX "G.V." c/o/ J. W. Vickers & Co., Ltd., 7/8 Great Winchester Street, London, E.C.2.

Applications are invited from senior physicists and engineers for work mainly in the field of electronics. Candidates must be capable of leading research groups and must have considerable electronic engineering experience. The Personnel Officer, Research Laboratories of The General Electric Co., Ltd., N. Wembley, Middx. will be pleased to receive applications giving details of age, experience and qualifications.

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Draughtsman required for design and development of Radio and Television Receivers, preparation of service diagrams etc. Knowledge of Radio an advantage, but not essential. Good all round man able to work with minimum supervision. A.E.S.D. rates paid. Apply Regentone Products Ltd., Eastern Avenue, Romford, Essex.

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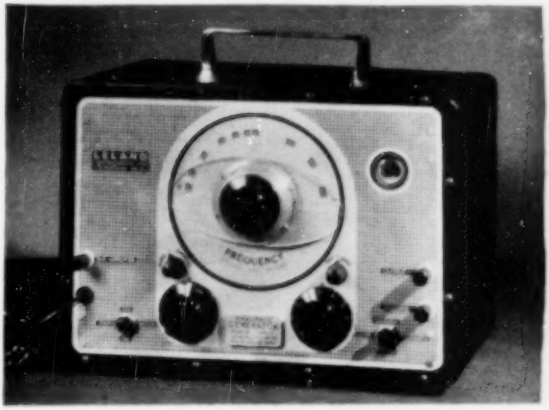

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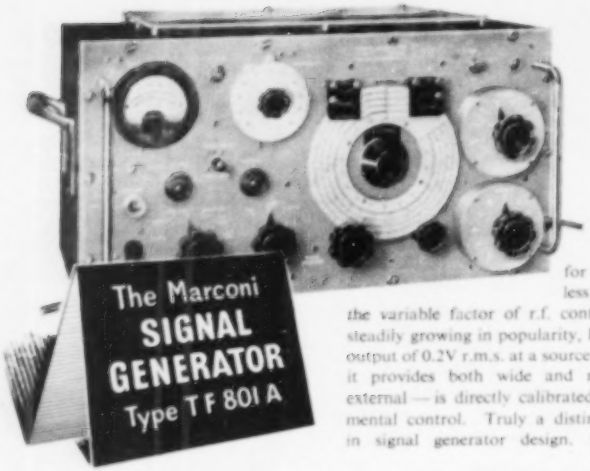

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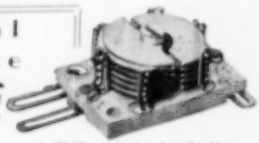

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.25	1¾in.	5/16in.
.5	2 in.	¼in.

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Cap. μF.	Lgth.	Dia.
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.1	1¼in.	5/16in.
.25	1¾in.	¼in.

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1000 V. D.C. Wkg.

Cap. μF.	Lgth.	Dia.
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.001	1 in.	¼in.
.005	1 in.	5/16in.
.02	1¼in.	¼in.
.1	2 in.	¼in.

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